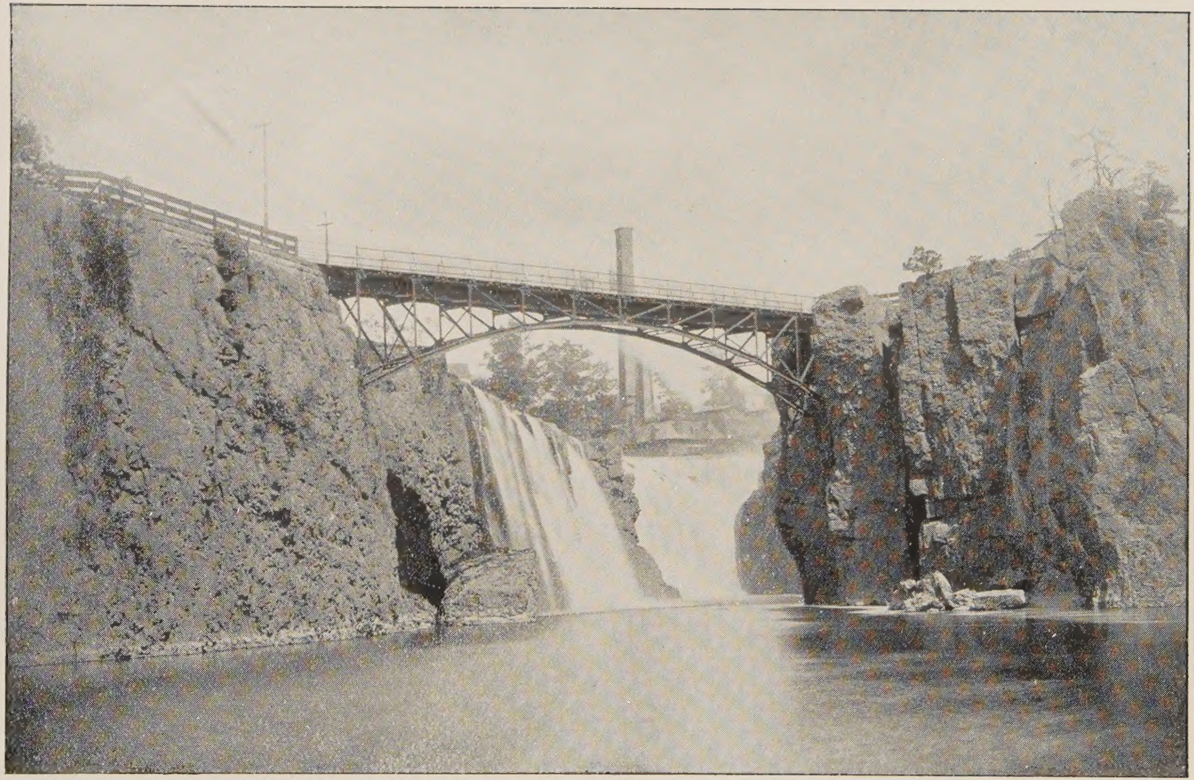

PASSAIC FALLS.

GEOLOGICAL SURVEY OF NEW JERSEY.

JOHN C. SMOCK, State Geologist.

REPORT

ON

WATER-SUPPLY,

WATER-POWER, THE FLOW OF STREAMS AND ATTENDANT PHENOMENA,

BY

CORNELIUS CLARKSON VERMEULE,

CONSULTING ENGINEER.

Volume III. of the Final Report of the State Geologist.

TRENTON, N. J.:
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LETTER OF TRANSMITTAL.

To His Excellency George T. Werts,
Governor of the State of New Jersey and *ex-officio* President of the
Board of Managers of the Geological Survey of New Jersey:

SIR—I have the honor herewith to submit Volume III. of the final report of the State Geologist.

With high respect,
Your obedient servant,
JOHN C. SMOCK,
State Geologist.

TRENTON, N. J., June 26th, 1894.

PREFACE.

The waters of the State have been recognized by the Geological Survey as a part of its mineral resources, and therefore as coming within the scope of its investigations and surveys. The hydrography has been included in the work of the topographic survey, and the surface-waters have been described in the first volume of this series of a final report. The courses of the streams and their drainage basins are shown in detail on the topographic maps of the State. Water as a mechanical agent in its action upon the surface and in relation to important facts in the geologic history has been studied carefully, and particularly in the form of ice in the glacial period.

The need of wholesome water for household consumption, as also good water for use in the arts, has prompted many inquiries about the available sources from which steady and abundant supplies of such water may be had, and the large number of these inquiries has demonstrated the necessity of gathering all of the facts relative to the occurrence of waters on the surface and in the earthy and rocky beds under it.

The first publication of the Geological Survey on the subject was in a chapter on "Water," in the "Geology of New Jersey," 1868. Chemical analyses of the waters of the larger rivers of the State and of a few typical well-waters were given in this volume. In the annual report of the State Geologist for the year 1874 the importance of good water for the supply of the cities and towns of the State was again discussed, and the Highlands were referred to as a desirable source for these supplies. In 1876 the question of public water-supply for the cities in the northeastern part of the State was put before the Board of Managers of the Survey by the authorities of these cities, and the help of the Survey was asked. A large part of the report for the year 1876 was devoted to the subject of water-supply, illustrated by a map of the Passaic drainage basin, and its lakes and sites for storage reservoirs. Many analyses were given to show the excellence of the waters of the Highlands and their value as compared with existing supplies. The data obtained by the field surveys and the laboratory work of that year have been useful in the general information afforded and in their practical application to the work of getting new city supplies in that part of the State. The importance of the subject has been still further shown in the space given to it in the annual reports published since 1876. Water-supply has become one of the leading topics. Our knowledge of the State and its natural waters given in these annual reports is due to the far-sighted and comprehensive views of the subject held by the late Prof. Cook, State Geologist, and expressed in the practical work which he started. The subterranean as well as the surface-waters were studied in their accessibility, volume and character, and the artesian wells along the Atlantic coast belt of the State are demonstrations of the accuracy of his studies.

The work for this volume on water-supply was begun in 1890, and was put in charge of Mr. C. C. Vermeule, the topographer and consulting engineer of the Geological Survey. His intimate knowledge of the physical geography of the State, obtained during his long service at the head of the topographic division of the Survey, was a most valuable basis for the study of the hydrographic features and a comprehensive treatment of the question of water-supply in New Jersey. Reports on the progress of the work have been made annually, and many facts on stream-flow, evaporation, rainfall and city consumption of water have been given in them. A census of the water-powers of the State was made in 1890 and 1891 and was published in the annual report for 1891. Observations upon stream-flow have been carried forward from the beginning of the work and careful gaugings of the large streams have been made. Valuable data relative to stream-flows in the adjacent Middle Atlantic and the New England States have been collected and discussed. In these reports on the progress of the work much information of practical value has been made accessible and available. The publication of the final results in this volume has been delayed beyond the time allotted to it when the work was begun. The longer periods of observation and the greater accumulation of data for a thorough discussion of the problems of rainfall, evaporation and stream-flow, and their relations to one another and to the various drainage basins of the State, have yielded results of permanent value in all studies of water-supply.

The large influence of geological conditions upon storage and delivery of ground-water is here shown clearly in the diverse phases of the streams of the northern and southern parts of the State, and the true bearing of evaporation and ground-storage upon stream-flow is demonstrated. The preponderating effect of temperature in determining the amount of evaporation and consequently the total run-off of streams for a given rainfall, and the entirely subordinate influence exerted by forests or other vegetation thereon, seem proven by these studies. These and other phenomena incidentally developed promise to be valuable sidelights upon other scientific and economic problems.

The indicated certainty of occasional periods of small rainfall, and the persistence of evaporation as determined by temperature for the various sections of the State, are suggestive of conservative estimates for the yield of water-gathering territory; but, on the other hand, the revelation of the important and reliable yield of ground-waters at such times gives greater confidence that our estimated minimum yield will not fail us.

The collation of much valuable data hitherto scattered and inaccessible, from sources without the State, the direction of his field-work so as to fill out these data and render them available for application to our own streams, and finally the careful study and analysis of the whole, have enabled Mr. Vermeule to produce a report which must become a hand-book to people of the State and of great value to all who may be engaged in like studies elsewhere.

The importance of this question of water-supply to our citizens, most of whom are dependent upon public water-supply systems, and its intimate relation to the general health, make it deserving of the time and space which have been allotted to it in this report. The subject is a growing one and the conditions are so rapidly changing that no report thereon can be considered final. The space here given to it is inadequate to its full discussion. It merely rounds out an epoch in the accumulation of information therein for public use.

JOHN C. SMOCK,
State Geologist.

TRENTON, N. J., June 26th, 1894.

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ERRATA.

Page.	Line.	
110	2	Below table, for "Philadelphia," read "New York."
133		Flow of Paulinskill, "1890-1891," should be "1890–1892."
174	31	For "Pompton lakes," read "Pompton Lakes."
181	15	For "developed," read "diverted."
229	3	For "Hobart," read "Stamford."
263	15	For "Cedar creek," read "Cedar Grove."
297	29	For "geological," read "microscopical."
303		Foot-note, for "Water-Supply Department," read "Water Department."
330	26	For "Minister," read "Commissioner."

APPENDIX I.

37		For "Newton creek," read "Newtown creek."

WATER-SUPPLY.

INTRODUCTION.

The task of preparing a report upon the hydraulic resources of the State, which should be a hand-book of our streams and a guide to their utilization for the supply of communities in search of more abundant or purer water for domestic consumption, or for water-power purposes, was first undertaken in 1890.

Since its inception the Survey has included these waters among the natural sources of wealth which it was designed to aid in the development of. In the Geology of New Jersey, 1868, a short chapter was devoted to the subject, and several analyses of river and well-waters published. In every annual report since 1874, it has received some attention; more and more as the growth of our city population has continued at a rapid rate, and the demand for a larger and better supply of water consequently increased. Then, too, our State and local Boards of Health have become vigilant and critical, and a more general observance of sanitary laws has caused the rejection of sources once considered adequate.

The completion of the topographic survey furnished full and accurate data as to the size of water-sheds, their configuration, extent of forests, facilities for artificial storage and much other information necessary for the intelligent study of our streams.

These conditions of better facilities for the work and steadily-increasing demand for its results made the time opportune for its undertaking. The greatest obstacle in the way was the lack of accurate measurements of the flow of our streams and of time in which to obtain series of gaugings covering periods long enough to embrace a sufficient range of rainfall and flow-off to make deductions therefrom safe and valuable. Our experience with such observations has led us to place little reliance upon the results of one or two years taken alone, although such short series may become valuable when used carefully in connection with longer series upon other similar streams. The consequence has been, first, that we have prolonged our investigations beyond the time originally allotted to them in order to perfect our data, and second, that we have proceeded to avail ourselves of all that had been done elsewhere in this line, which would apply to our conditions. Some long series of gaugings on water-sheds resembling our own in location and topographical conditions have been collected, re-arranged and are published for comparison and study.

The time was thought to be too brief to obtain such long series for our own streams, but we proceeded to collect such data as would enable us to compare them with those for which we had gaugings. Fortunately, we have had placed at our disposal records which have enabled us to compute the flow of the Passaic for seventeen years, and thus to add a valuable contribution to the study of this subject of stream-flow. It is to be noted that this Passaic series and the similar Croton series together cover a period of over a quarter of a century, and therefore practically all the conditions of rainfall which are likely to occur at any time. We are especially fortunate in obtaining so many good series typical of New Jersey water-sheds, and with the shorter ones which we have from our own gaugings, we feel that we have quite enough data for reliable deductions.

From these long-series observations we have attempted to devise a formula for computing stream-flow which would conform to observed phenomena and be generally applicable to all streams, believing such a procedure to be quite possible and more practical and consistent than any method of treatment of the subject which we found ready at hand.

It is with much hesitation that we undertake here the application of a theory that is entirely new, but we must plead necessity as our excuse. The methods which have prevailed in computing stream flow heretofore have not been, and have scarcely pretended to be, scientific and natural. They do not follow natural laws. The fundamental idea seems to be that the amount of water flowing off of a given area within any given period is some percentage of the rain falling upon that area in such a period. A moment's reflection will show the fallacy of such reasoning. We have records of many months in which the rainfall was less than evaporation and not a particle of rain reached the streams, yet in those months the streams continued to flow and yield a substantial amount of water. Again, we have many instances in our records of flow, during the winter and early spring months, when the total stream-flow was much greater than the total rainfall, and, indeed, such a state of affairs is not uncommon for summer months also. Any system of percentages in such cases leads to blunders too absurd to be tolerated. The impossibility of making any system of percentages yield results in accord with what is actually shown in our tables of rainfall and flow, forced us to seek some more reliable method of estimating the flow of our streams, and we hope that the results will find approval. Indeed, our experience has taught that percentages and averages, when applied to stream-flow, not only give erroneous results, but hide the truths which would otherwise be apparent enough. In consequence we have carefully avoided such percentages and averages in making our analyses.

The reader who has followed the results of our studies in the annual progress reports, and who now compares them with the formulæ and method adopted in this book, will appreciate that we have not stumbled upon our method. It has been a slow and halting progress, always on the same lines but starting out with some natural obscurity. These annual reports are now entirely superseded by this book, and you are in all cases to accept this as correct where a difference is noted in data or conclusions. It is based on fuller observations and a clearer conception of the laws of stream-flow, evaporation, demands of vegetation and quantity and rate of delivery of ground-waters, than we possessed in 1890, or even one year ago.

Even up to the hour of going to press the collection of data has proceeded, and we have found it necessary to confine our work to that portion which was in hand long enough before to admit of its careful reduction and analysis. The present report, therefore, must not be considered final in the sense that it is conclusive, and the results here given may yet be subject to modification. We only claim for them greater accuracy than has heretofore been attainable.

We are also aware of certain imperfections in our formulæ, some of which we have pointed out in applying it and all of which we have furnished the means of judging of. Most of these imperfections might be corrected, excepting that we have feared to make the method too complicated for easy practical application.

We are especially pleased that the results as to the amount of water collectible, given by our system of computation, are so well in accord with the conclusions of the more conservative hydraulic engineers. Such conclusions, based on the experience of a remarkably careful and competent body of observers, are not likely to be far from the truth, and it is especially gratifying to have been able to verify them by a method which does no violence to natural law in any of its stages of reasoning. We do differ from some authorities in ascribing causes for variation in the yield of streams for a given rainfall and in other incidental matters; but as to most of these, they are not well agreed, and we trust that they will find little difficulty in accepting our conclusions as to such minor details.

In estimating the supplying capacity of a water-shed, it is always very important to be conservative. A failure of the supply may lead to disastrous results, while an excess is always to be looked for in years of heavy rainfall. Our records on the Passaic, for instance, show yearly rainfalls ranging from 36.68 inches to 70.88 inches, and a yield of the stream of from 16.56 to 42.23 inches.

With a very large reservoir capacity, it might be thought possible to carry over stored water from the full years to the deficient ones, but the danger of any attempt of this kind is well shown by the records of flow during successive dry years on the Croton, Sudbury and Passaic. It will be noted that frequently the flow for eighteen consecutive months or so, embracing parts of two years, will be at a lower rate than that shown by the least calendar year.

There seems to be a tendency towards periods in rainfall which exposes us to the danger of two or more years of low rainfall coming in succession, consequently our basis in computations of this character must be the yield for the driest period.

The water-supply resources of New Jersey are excellent, and if they are judiciously developed will support the needs of a very large population, but the present and prospective demands are also large.

In 1882 the population in the State dependent upon systems of public water-supply amounted to 587,660, using 48,923,406 gallons daily. In 1894, 1,114,403 persons were supplied with 107,840,361 gallons daily. In twelve years the population supplied nearly doubled and the consumption of water had increased 120 per cent. The per capita consumption now averages 97 gallons daily, and ranges from 60 gallons in towns of less than 15,000 population to 149 gallons in the city of Camden. Of the total supply in 1894, about 8,000,000 gallons daily was drawn from wells and 100,000,000 from streams.

The southern New Jersey cities are rapidly increasing in size and importance, and this subject is demanding more and more attention from them, but it is in the northeastern counties that it assumes the greatest importance. This is not alone due to the large urban population within our own borders, but to the great and growing metropolitan district of which it forms a part. This district may be taken to include the counties of Hudson, Essex and Union, with Passaic northward to Paterson, and Bergen to Hackensack and Englewood, in our own State; New York, Kings and Richmond, with Long Island City and Newtown in Queens county, in the State of New York. Practically, all of the population thus included will soon be dependent upon public water-supply. Its magnitude and growth are shown in the following table compiled from the United States census:

YEAR.	METROPOLITAN DISTRICT.		NEW JERSEY PORTION OF SAME.		NEW YORK CITY.	
	Population.	Per cent. increase.	Population.	Per cent. increase.	Population.	Per cent. increase.
1840......	453,374	....	72,404	....	316,392	....
1850......	798,066	76.0	116,932	61.8	519,983	64.4
1860......	1,375,400	72.3	224,617	92.0	830,369	60.0
1870......	1,815,454	32.0	370,957	65.0	971,273	17.0
1880......	2,387,910	31.5	516,192	39.1	1,206,299	24.2
1890......	3,180,038	33.2	726,442	40.8	1,515,301	25.6

For the last three decades the whole district has increased in population quite uniformly at the rate of 32.2 per cent. per decade. The New Jersey portion has preserved an increase of 40 per cent. for the last two decades. We may estimate the future increase at 30 and 40 per cent. respectively. This gives the following future population:

	Metropolitan District.	New Jersey Portion of the Same.
1900..................................	4,134,000	1,017,000
1910..................................	5,374,000	1,424,000
1920..................................	6,986,500	1,993,000
1930..................................	9,082,000	2,791,000
1940..................................	11,807,000	3,907,000
1950..................................	15,349,000	5,470,000

The present consumption in this district averages closely 100 gallons daily per capita. At this rate, the whole supply needed will amount to 1,500,000,000 gallons daily by 1950. Our investigations show that the supplying capacity of the neighboring water-sheds for the driest year does not exceed 14 inches of rainfall. This amounts to practically two-thirds of a million gallons daily for each square mile of water-shed, and the above demand will require the total yield of 2,250 square miles of water-shed, the equivalent of three streams as large as the Passaic above Paterson.

While the demand thus increases, the supply of pure and wholesome water near at hand decreases because of the encroachments of population and its attendent defilement of streams. This whole area must shortly be supplied from sources without, and it is the consideration of these facts which has led to investigation of available sources of supply.

This great prospective demand for potable waters and wholesome gathering-grounds in the vicinity of our northeastern cities is of interest to our citizens, but they are even more directly concerned with the demand which will arise within our own borders. By 1950 our estimate shows that the New Jersey portion of this population will itself require a supply of 547,000,000 gallons daily, or the total yield of 820 square miles of drainage area. It will not be an easy matter to find so much water as this without going to the Delaware river or its tributaries. Since fifty years cannot be considered a long time in the future for which to make provision, it is evident that the time has come for us to know what our resources are and to provide for their preservation and wise development.

Our Highland water-sheds, to which we call attention more fully hereafter, must be the first source from which this demand is to be met. They lie convenient to the metropolitan district, at a sufficient elevation for delivery of their waters by gravity, are not populous, have just the right amount of forest, geological and topographical conditions favorable to purity, and if they could be preserved in their present favorable condition would form in all respects an ideal gathering-ground. They have already begun to be utilized, and every succeeding decade must see a more rapid advance in their development. They are also threatened at points with pollution.

Their protection and conservation for the future needs of the State seem to be merited by their unusual excellence.

The present report deals largely with the peculiarities of our water-sheds favorable or unfavorable to purity rather than with chemical analyses to indicate the fitness of streams for water-supply. The examination of a water-shed will reveal to the experienced eye its fitness or unfitness for such purpose, and will indicate what analyses may be expected to reveal. Such analyses, in order to be reliable indications of the quality of a stream, should be taken at intervals throughout at least one year. A water-shed may show upon examination elements of danger which no careful sanitarian can ignore, yet one or two analyses may fail to indicate the presence of anything deleterious in the waters. If, on the other hand, the examination of a water-shed shows conditions naturally favorable to purity, yet a given analysis reveals elements of danger, it will usually be found that these are traceable to accidental or artificial causes which are within the reach of ordinary remedies. In brief, we cannot make up for the lack of general conditions favorable to purity. Such conditions are usually permanent, and their presence or absence is of first importance in selecting a source of public water-supply. For this reason we have, in general, considered it preferable to leave chemical and microscopical examinations to be made as they are needed.

We have published a collection of chemical analyses and have supplemented these by a few made especially for this report, but the principal aim in view has been not to detect or indicate pollution, but rather to give a good idea of the chief chemical characteristics of our stream-waters in their natural state, and of those known to be badly polluted. The whole is designed as a general guide to which future analyses may be referred, or for purposes of comparison of various classes of streams.

In this, as in all, the report deals primarily with the natural resources of the State, without attempting any examination or criticism of existing systems of public water-supply. Where the streams are known to have become dangerously contaminated or to be seriously threatened attention is called to the fact, but conditions of population and sources of contamination are undergoing so rapid a change in many parts of the State that chemical or microscopic analyses, however elaborate, made now are almost sure to become valueless, and may become misleading a few years hence.

Next to the subject of water-supply comes that of water-power. There are many reasons why a study of these two should go hand in hand, but foremost are the facts that both need the investigation of amount of available stream-flow and that the two interests come continually into conflict. Such an investigation must be an aid in determining the proper status and importance of each and in directing their development on lines which will reduce the probability of serious interference. The water-power interests of the State have never before received much attention. For a time an impression prevailed that water-power had passed its day of usefulness, and property of this character was depreciated in consequence. The error of this is demonstrated by the results of our canvass of the water-powers. The amount of water-power in use has never been as great as at present.

Taking the census figures for 1870 and 1880, and comparing them with our own, we have:

	1870. Net H. P.	1880. Net H. P.	1890–91. Net H. P.
Total power in use	25,832	27,066	30,870
Flouring and grist-mills	11,108	12,183	12,880
Saw-mills, &c	....	3,903	4,085

This shows a small but steady increase in each decade, amounting in the last to 14 per cent. It does not show the real changes which have taken place, for there has been a steady loss of small, inefficient water-powers, which had to be made good by the construction of larger and better-equipped plants. Many small saw and grist-mills have thus been abandoned, the former because of scarcity of timber, and the latter from the competition of large, well-equipped modern mills. Where the stream is of sufficient capacity, these large plants are erected upon the sites of the small mills; otherwise these sites are abandoned and new ones developed.

It is the existence of many of these small, insignificant, abandoned water-powers which has given rise to the impression that the use of water-power is decreasing. The fact has been overlooked that a single water-power plant such as that of the Dundee Water-Power and Land Company, at Passaic, is equal to all of the abandoned forge-powers in the State. The two efficient plants recently erected on the Musconetcong by the Warren Paper Company, with 700 net horse-power, are equal in power to thirty of the abandoned saw-mill powers. Water-power is not falling into disuse in New Jersey; on the contrary, it is being used more efficiently than ever before. The cordial sympathy and interest which the owners and users of water-power have shown in our work, and the substantial aid which they have given, show that they feel the need of such an investigation as has been undertaken.

The above-mentioned considerations, and the fact that the increasing use of electricity and possibilities of electric transmission of power are opening up new fields for its use, make the time peculiarly auspicious for laying before the public a statement of our water-power resources, and calling special attention to our large, undeveloped powers. Indeed, at the time of this writing experiments are being made in transmitting power electrically for the propulsion of boats on the Erie canal, and a large plant is being installed for transmitting the power of Niagara Falls for use in the shops and manufactories of Buffalo, in our neighboring State.

If the unused water-power of our State can be transmitted to our great manufacturing centers to drive machinery, or applied to the propulsion of cars in the streets of our cities, a distinct economic gain will result as surely as from the development of our mineral or agricultural resources. An inquiry for water-power will certainly follow the application of electric transmission, and we look for a marked impetus to be given to its utilization.

We have no disposition to ignore the limitations of water-power, or to claim for it more than its just due. Competition and the prevailing tendency to lower prices call loudly for economies in cost of production, and cheap power may play an important part in the future of some of our industries. We have presented the bald facts as to the available power of our streams, and believe that the prevention of unwarranted expectations is as great an aid to future development as the presentation of the resources. Those who are competent to properly weigh the facts presented, and apply them to their own particular case intelligently, will probably be able, now and then, to discover and avail themselves of substantial advantages in the use of this kind of power. These will welcome this aid to a correct decision. It is only such intelligent and well-directed enterprise which will permanently promote the use of water-power and advance the interests of the State.

Besides the application of the studies here made to the uses indicated by our title, we may mention that such an investigation should be a direct aid in designing drainage or irrigation works, in controlling floods or building bridges.

The main facts as to the estimated flow of the various classes of streams are presented in Tables No. 51 to No. 61 A, inclusive. To apply these to any particular stream of the class at any given point, it is only necessary to know the area drained by the stream, expressed in square miles, and to apply this as a multiplier to the flow there given in thousand gallons daily per square mile, or the horse-power per square mile on one foot fall, to ascertain the capacity of the stream considered. Many such areas are given in Appendix II.

As we have already remarked, this report is intended to be a practical hand-book of the streams of the State. The flow of streams, however, is merely one, and rather an incidental one at that, of a chain of related phenomena. It is nature's way of removing the surplus rainfall after evaporation and plant-growth have been supplied. Any rational discussion of stream-flow, therefore, must begin with a determination of the amount of rainfall, and must next ascertain the laws of evaporation and the amount of water thus disposed of, as well as the amount required by vegetation at different seasons, and the absorption and delivery of ground-waters. As each of these subjects has a wide and important bearing outside of the immediate field of our report, it follows that incidentally a thorough investigation of our subject must throw light upon other important economic and scientific questions. We regard the accurate ascertainment of the relations of rainfall, temperature, evaporation and ground-water depletion, such as is attempted by our formulæ, as almost as important to agriculture, forestry, climatology, and possibly hygiene, as it is to the subject of this report, but we have gone no farther herein than to incidentally suggest these applications.

It would be a pleasure to be able to acknowledge our indebtedness to all those who have so cordially aided us in our work, directly and indirectly, but we find it impossible to do so. Many prominent hydraulic engineers have contributed data, most of the users of water-power in the State are entitled to our thanks, and there has been a general disposition to aid and encourage our investigations.

Messrs. Cyrus F. Sproul, Asher Atkinson, Peter D. Staats, George E. Jenkins and D. H. McLaury have assisted in gauging and collecting data, and Mr. J. R. Prince has prepared the maps and diagrams and done much of the mathematical work. The collation of data collected, the reduction of gaugings and comparison, arrangement and re-arrangement of measurements of flow and rainfall necessary to discover the laws governing the flow of streams, has been a labor of great detail, most of which, of course, does not appear in the results.

THE LAWS WHICH GOVERN STREAM-FLOW.

As a preliminary step to any intelligent study of the flow of streams, we must consider the causes which give rise to the phenomenon.

The waters of the earth are taken up by the process which we call evaporation and formed into clouds, to be again precipitated to earth in the form of rain or snow. Of the water which falls upon the basin of a stream, a portion is evaporated directly by the sun; another large portion is taken up by plant-growth and mostly transpired in vapor; still another portion, large in winter but very small in summer, finds its way over the surface directly into the stream, forming surface or flood-flows; finally, another part sinks into the ground to replenish the great reservoir from which plants are fed and stream-flows maintained during tle periods of slight rainfall, for the rainfall is frequently, for months together, much less than the combined demands of evaporation, plant-growth and stream-flow. These demands are inexorable, and it is the ground-storage which is called upon to supply them when rain fails to do so.

All of these ways of disposing of the rain which falls upon the earth may be classed as either evaporation or stream-flow. Evaporation we make to include direct evaporation from the surface of the earth, or from water-surfaces, and also the water taken up by vegetation, most of which is transpired as vapor, but a portion of which is taken permanently into the organisms of the plants. Stream-flow includes the water which passes directly over the surface to the stream, and also that which is temporarily absorbed by the earth to be slowly discharged into the streams. A portion, usually extremely small, passes downward into the earth and appears neither as evaporation nor as stream-flow. It is usually too small to be considered, and we may for our purposes assume that all of the rain which falls upon a given water-shed and does not go off as stream-flow is evaporated, using the latter word in the broadened sense which we have above described.

We therefore have to consider first rainfall as the source of supply, and secondly evaporation and stream-flow as the demand to be supplied.

RAINFALL.

The best source of information as to the rainfall of the State is the Climatology, published by the Survey in 1888, which contains collections of all data obtainable to that date. The State Weather Service now publishes monthly bulletins and yearly reports, giving the rainfall by days at some fifty stations. This work has been of the greatest assistance in connection with our recent gaugings, and when it is continued long enough we shall have much more accurate knowledge as to the distribution of rainfall than we have at present. Much information has also been promptly furnished us by the United States Weather Bureau. The records given in the Climatology, supplemented by later data now obtainable, have furnished the basis of our conclusions as to rainfall for use in this report. The long series of rainfall tables published at the end of this chapter we regard as more valuable to the hydraulic engineer than averages or deductions. These we shall make, however, for simplicity in generalization.

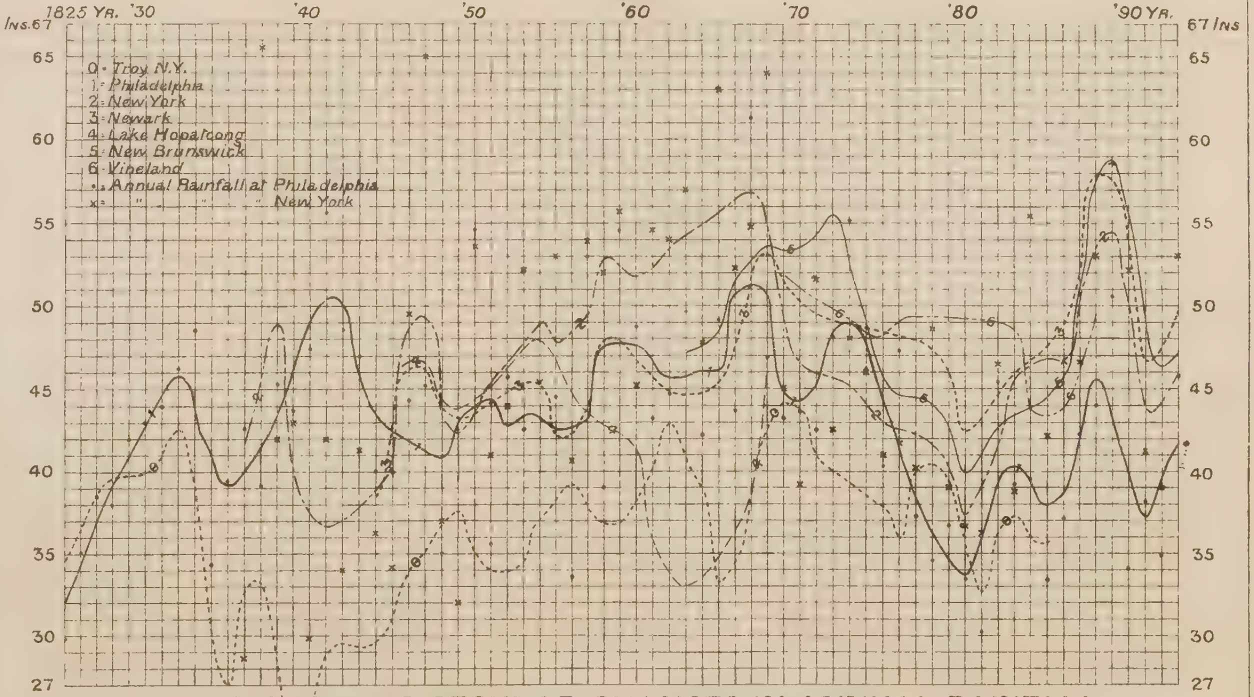
A careful study of these long series shows a strong tendency to cycles of high and low precipitation. We are likely to have a period of years of high average rainfall, followed by a low period. We see at once that, under these conditions, differences shown by comparing a series of eight or ten years' length at one station with a fifty or sixty-year series at another, may be entirely differences of time and not of place.

Plate I. shows this clearly. The annual rainfall is here plotted by taking for each year the average of that year, the preceding and the following year. Curves thus obtained are slightly smoothed out, but in no case departed from by more than one inch in annual rainfall. These type curves show unmistakably the tendency of which I have spoken. They cover 69 years at Philadelphia, 61 years at Troy, 58 years at New York, 50 years at Newark and shorter periods at the other stations.

While the maxima and minima do not always agree in time at different stations, it is nevertheless clear that, upon the whole, it is safest to compare cotemporaneous periods if we wish to ascertain the relative rainfall at two or more stations. I have consequently proceeded upon this plan in deducing rainfall averages for the several sections of the State.

This diagram shows clearly, also, the danger of placing too much confidence upon observations at a single rainfall station. The Lake

Plate 1.



CURVES SHOWING SECULAR CHANGES IN ANNUAL RAINFALL.

JULIUS BIEN & CO N.Y.

J R Prince Del.

Hopatcong record has been much quoted as indicating the rainfall of our Highland region, but the curve shows that while most of the other stations were showing more than average rainfalls, at about 1863, Lake Hopatcong was passing through a remarkably dry period.

If we compare the average rainfall at this station during the 24 years covered by its record with the average at New York for the same time we find it 8 inches less, and it is 4.2 inches less than Philadelphia. The curve of Plate I. strongly suggests, however, that this relation might be reversed during another period, and undoubtedly it is not safe to judge the rainfall of any considerable part of the Highlands by this record alone.

It might be interesting to trace the reasons why these variations occur, such as the effect of the prevailing direction of the wind upon the exposure of a given station, especially in hilly regions, but such matters are beyond the scope of this report. Study of cotemporaneous records convinces me that this variation is purely local—too local to affect the yield of even a small water-shed appreciably.

Plate I. is, finally, useful in pointing out the danger of basing conclusions upon a short series of rainfall or stream-flow observations without referring such observations to some long-period series with which it is comparable.

We see here that the ratio between the three series at New York Newark and Philadelphia varies with different periods. The variation between places as near as New York and Newark, even, is very considerable. This warns us that our next hypothesis may not be strictly accurate. It is that the ratios here shown between each place and the average of New York and Newark for the period of observation will be preserved for the fifty years covered by the cotemporaneous observations at New York and Newark. Nevertheless this supposition will eliminate the error arising from comparing periods not cotemporaneous and of unequal length, and will thus lead us as near the truth as we can get from the light we now have. It is on this hypothesis that we have computed the average annual precipitation for each place shown in the last column of Table No. 1.

We have grouped these places as follows in order to determine the average annual precipitation for various sections of the State, and when so grouped certain well-defined differences of rainfall appear:

The Seacoast.—This includes stations Sandy Hook, Barnegat, Atlantic City, Cape May and Norfolk, Va. Atlantic City shows a lower rainfall than the others, and this we consider purely local.

TABLE No. 1.

Annual Precipitation for Cotemporaneous Periods, With Deduced Average Annual Precipitation.

PLACE.	Time covered by record.	Average annual precipitation.	PRECIPITATION DURING SAME PERIOD AT—			Average deduced from New York and Newark series.
			New York.	Newark.	Philadelphia.	
New York	1836–1892	46.12	46.12	....	44.11	46.12
Newark	1843-1892	46.68	46 18	46.68	43.77	46.62
New Brunswick	1854-1892	46 90	46.64	47.26	43.00	46.43
Trenton	1866–1880	47.55	46.02	48.21	44.01	46.92
Morrisville, Pa	1798–1866	43.66	....	....	....	....
Philadelphia, Pa	1825–1892	43.35	....	....	43.35	44.11
Baltimore, Md	1836-1887	41.98	45.05	....	44.47	42.33
Sandy Hook	1874-1886	51.08	42 99	46.00	38.54	53.39
Freehold	1874–1883	46.73	41.17	45.85	39.09	49.73
Barnegat	1874-1885	48.31	42.68	45.82	38.65	50.66
Moorestown	1863-1887	43.23	46.82	47.41	42.76	44.71
Atco	1872–1882	46.76	42.40	47.00	41.40	47.54
Vineland	1866–1886	48.27	45.54	47.40	42.18	48.28
Atlantic City	1874-1887	42.55	43.25	46.33	38.80	44.16
Cape May	1871–1885	47.10	43.60	46.69	40.66	48.43
Greenwich	1864-1873	41.53	50.79	48.87	47.61	39.04
Dover, Del	1870-1881	43.95	42.52	....	....	45.73
Norfolk, Va	1870-1891	52 20	45.08	48.46	40.90	51.91
Perkiomen Water-Shed, Pa	1884–1892	49.32	48.33	50.19	39.33	46.54
Neshaminy Water-Shed, Pa	1884–1892	49.22	48.33	50.19	39.33	46.44
Tohickon Water-Shed, Pa	1884–1892	51.46	48.33	50.19	39.33	48.68
Easton, Pa	1884–1892	49.34	48.33	50.19	39.33	46.56
Bethlehem, Pa	1878–1889	43.55	45.71	....	....	43.00
New Germantown	1869–1876	44.09	44.36	48.30	45.84	44.24
Somerville	1878–1887	44.62	43 68	45.86	40.94	46.33
South Orange	1871–1892	48.64	52.18	55.85	46.90	43.03
Lake Hopatcong	1846-1869	42.54	50.49	45.31	46.75	41.73
Newton	1882–1886	44.86	45.93	....	....	45.00
Port Jervis	1880–1884	42.39	43.91	43.69	37.62	45.08
Blooming Grove, Pa	1867–1891	44.20	44.78	....	....	44.28
Honesdale, Pa	1882–1891	43 17	48.14	50.35	....	40.40
Liberty, N. Y	1851–1860	47.79	48.22	44.87	....	48.23
Passaic Water-Shed	1877–1892	46.77	45.08	48.13	38.19	46.65
Croton Water-Shed	1868–1881	44.64	44.27	47.67	....	45.15
Connecticut Water-Shed	1871–1878	43.84	44.88	48.96	....	43.40
Sudbury Water-Shed	1875-1890	45.80	45.22	48.20	....	45.58

Bearing in mind that Atlantic City has between it and the mainland six miles of meadow and bays, this station may represent rather seaward than coast-line rainfall. The other stations range well with our average.

Southern Divide.—This includes stations Freehold, Atco and Vineland.

Lower Delaware Region.—Includes Philadelphia, Moorestown, Greenwich and Dover, Del.

Central Delaware Valley.—Includes Philadelphia, Trenton, Neshaminy water-shed, Tohickon water-shed, Easton and Bethlehem.

Red Sandstone Plain.—Includes Trenton, Neshaminy and Perkiomen water-sheds, New Brunswick, Somerville, New Germantown, Newark, South Orange, Passaic water-shed, New York. These stations show annual precipitation ranging close to our average.

Highlands and Kittatinny Valley.—Stations Easton, Bethlehem, Port Jervis, Newton, Lake Hopatcong, New Germantown and South Orange are included in this region.

Upper Delaware Valley.—This includes stations Easton, Bethlehem, Newton, Port Jervis, Blooming Grove, Honesdale and Liberty.

As to the distribution of rainfall by seasons and months our data are not sufficient for very refined deductions, nor is it likely that we are to be better informed in the near future. It is safe to say that the monthly and seasonal ratios are likely to change from year to year until our records cover much longer periods than they do at present. We have arranged the following table, showing the percentages of precipitation falling in each season, as shown by records at hand. It is noticeable that the longer series harmonize better than the shorter:

Percentage of Annual Precipitation Falling in Each Season.

	Years of record.	Spring.	Summer.	Autumn.	Winter.
		per cent.	per cent.	per cent.	per cent.
New York	57	25	28	23.5	23.5
Newark	45	25	28	23.5	23.5
New Brunswick	34	25	30	23	22
Morrisville, Pa	45	25	27	27	21
Philadelphia, Pa	68	24.5	28.5	23.5	23.5
Baltimore	52	25	28	24	23
Sandy Hook	13	27	26	23	24
Atco	10	21	30	25	24
Vineland	21	23	27	23	27
Barnegat	12	22	25	26	27
Cape May	14	23	27	23	27
Atlantic City	14	22	26	24	28
Bethlehem, Pa	12	22	31	22	25
Port Jervis, N. Y	5	25	29	21	25
Lake Hopatcong	24	25	28	27	20
Goshen, N. Y	8	24	26	25	25
Blooming Grove, Pa	27	24	32	24	20

Arranging these in groups, we find the distribution for the several districts to be as follows:

	Spring.	Summer.	Autumn.	Winter.
	per cent.	per cent.	per cent.	per cent.
Seacoast	22	27	24	27
Southern divide	22	27	24	27
Delaware bay	25	28	23.5	23.5
Central Delaware valley	25	28	23.5	23.5
Red sandstone plain	25	28	23.5	23.5
Highlands and Kittatinny valley	24	28	24	24

At first sight we seem to have a marked difference of distribution by seasons, but here again we find it to be rather a difference of period than of locality. The records for the Seacoast and Southern divide cover, mainly, years from 1870 to 1887, and the New York record for this period shows about the same distribution, varying greatly from the average of the New York series. On the whole, we shall be nearer the truth, probably, if we accept the distribution shown by the long New York and Philadelphia series as correct for all of our State. This gives us Table No. 2.

An examination of the results given in this table shows a gradual decrease of rainfall as we proceed inland. The range is from 49.70 inches on the seacoast to 44.09 in the Highlands and Kittatinny valley, and 43.25 for the Lower Delaware region. The rainfall of the Raritan water-shed is assumed to be the same as that of the Red sandstone plain, that of the Passaic a mean of this and the Highlands, that of the Coast streams a mean of the Seacoast and Southern divide, that of the branches of the Delaware below Camden a mean of the Southern divide and Lower Delaware, and that of the branches of the Delaware, Camden to Trenton, a mean of the Southern divide and Central Delaware valley.

Even more important than the average rainfall are the least rainfall and that of ordinary dry years. A study of available data convinces us that we must expect in all parts of the State occasional droughts as severe as those shown in the Philadelphia and New York records. Such droughts appear to be confined to rather limited areas and it is probably true that water-sheds exceeding from 75 to 100 square miles in extent will never be visited by quite such severe ones, but in order to include the smaller areas and be always on the safe side we must assume a minimum as small as that of the driest periods of these records. For convenience of future reference, and as an aid in selecting the driest period, we have prepared Table No. 3.

TABLE No. 2.

Average Annual and Monthly Precipitation by Sections and Drainage Basins.

	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	YEAR.
New York ratios	.078	.077	.083	.078	.090	.084	.090	.100	.080	.074	.083	.083	1.00
Philadelphia ratios	.080	.071	.082	.080	.087	.090	.095	.100	.082	.076	.078	.079	1.00
Adopted ratios	.079	.075	.081	.079	.088	.088	.092	.100	.081	.075	.081	.081	1.00
Upper Delaware valley	3.52	3.35	3.62	3.52	3.93	3.93	4.11	4.46	3.62	3.35	3.62	3.62	44.65
Highlands and Kittatinny valley	3.48	3.31	3.57	3.48	3.88	3.88	4.05	4.42	3.57	3.31	3.57	3.57	44.09
Central Delaware valley	3.63	3.45	3.72	3.63	4.04	4.04	4.23	4.59	3.72	3.45	3.72	3.72	45.94
Red sandstone plain	3.63	3.45	3.72	3.63	4.04	4.04	4.23	4.59	3.72	3.45	3.72	3.72	45.94
Southern divide	3.83	3.64	3.93	3.83	4.27	4.27	4.46	4.84	3.93	3.64	3.93	3.93	48.52
Seacoast	3.93	3.73	4.02	3.93	4.37	4.37	4.59	4.97	4.02	3.73	4.02	4.02	49.70
Lower Delaware	3.42	3.24	3.50	3.42	3.81	3.81	3.98	4.33	3.50	3.24	3.50	3.50	43.25
Delaware above Trenton	3.57	3.40	3.67	3.57	3.99	3.99	4.17	4.52	3.67	3.40	3.67	3.67	45.29
Raritan	3.63	3.45	3.72	3.63	4.04	4.04	4.23	4.59	3.72	3.45	3.72	3.72	45.94
Passaic	3.55	3.38	3.64	3.55	3.96	3.96	4.14	4.50	3.64	3.38	3.65	3.65	45.00
Coast streams	3.88	3.69	3.97	3.88	4.32	4.32	4.53	4.91	3.97	3.69	3.97	3.97	49.10
Branches of Delaware below Camden	3.62	3.44	3.72	3.62	4.04	4.04	4.22	4.58	3.72	3.44	3.72	3.72	45.88
Branches of Delaware, Camden to Trenton	3.73	3.55	3.82	3.73	4.16	4.16	4.35	4.71	3.82	3.55	3.82	3.82	47.22

TABLE No. 3.

Dry Periods—New York and Philadelphia Rainfall.

	Number of months.	TOTAL RAINFALL FOR PERIOD.			
		Driest.	Second.	Third.	Fourth.
New York, August, 1842, to July, 1843	12	25.48			
New York, January to December, 1836	12		27.57		
Philadelphia, January to December, 1825	12			29.57	
New York, January to December, 1840	12				29.80
New York, September, 1842, to July, 1843	11	22.67			
New York, January to November, 1836	11		25.27		
Philadelphia, January to November, 1825	11			25.85	
New York, February to December, 1840	11				27.96
New York, October, 1842, to July, 1843	10	20.57			
Philadelphia, March to December, 1881	10		21.79		
New York, January to October, 1836	10			23.37	
Philadelphia, January to October, 1825	10				24.49
New York, November, 1842, to July, 1843	9	16.27			
Philadelphia, April to December, 1881	9		17.96		
Philadelphia, October, 1879, to June, 1880	9			18.59	
New York, January to September, 1849	9				20.22
New York, December, 1842, to July, 1843	8	14.47			
Philadelphia, April to November, 1881	8		15.32		
New York, April to November, 1881	8			16.54	
Philadelphia, October, 1879, to May, 1880	8				16.92
New York, January to July, 1843	7	11.97			
Philadelphia, April to October, 1881	7		13.30		
New York, January to July, 1849	7			14.04	
New York, April to October, 1881	7				14.18
New York, February to July, 1843	6	9.97			
Philadelphia, April to September, 1881	6		10.26		
New York, July to December, 1881	6			11.22	
Philadelphia, January to July, 1880	6				12.11
New York, July to November, 1881	5	7.04			
New York, March to July, 1843	5		7.67		
New York, January to May, 1836	5			7.70	
Philadelphia, July to November, 1881	5				8.14
New York, July to October, 1881	4	4.68			
New York, April to July, 1843	4		5.54		
Philadelphia, July to November, 1881	4			6.12	
New York, April to July, 1849	4				6.30
Philadelphia, July to September, 1881	3	3.08			
New York, July to September, 1881	3		3.08		
New York, May to July, 1843	3			3.40	
New York, January to March, 1836	3				4.41

We find the year 1842–1843 the driest for all periods from six months upward, while for five months or less the year 1881 stands first, and occupies second place from six to ten months. If we accept the records as of equal accuracy and weight, the driest year of the series must be taken to be from August, 1842, to July, 1843. This year is shown to be dry by both the New York and the Philadelphia record, and it was also very dry by common repute. The claims for the years 1825, 1836, 1840 and 1849 are not so well established. There is a suspicion that in some of these cases the droughts were purely local, and in others that the records are less reliable than those for recent years. The year 1881 included a memorable drought, and one so widely extended as to embrace our largest water-sheds. Moreover, it followed a dry year and was consequently a severe one upon the streams. The yield of a stream during two such successive dry years as 1880 and 1881 would be for most purposes the minimum so far as our records go.

We repeat below for convenience of reference the rainfall at New York and Philadelphia during the period from December, 1841, to November, 1843, and from December, 1879, to November, 1881, which we have selected as typical dry periods.

TABLE No. 4.

Typical Dry Periods.

NEW YORK RECORD.

	December.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	YEAR.
1841–1842.....	2.70	1.07	2.85	1.25	3.60	3.60	3.30	3.80	2.81	2.10	4.30	1.80	33.18
1842–1843.....	3.50	1.00	2.31	2.13	2.14	1.00	0.76	1.64	15.26	3.06	5.91	2.82	41.53
1879–1880.....	4.94	2.02	2.12	4.66	2.90	0.62	1.14	8.53	5.26	1.85	2.81	2.46	39.31
1880–1881.....	2.27	4.80	4.93	5.81	0.95	3.20	5 35	1.25	0.86	0.97	1.60	2.36	34.35

PHILADELPHIA RECORD.

1841–1842.....	5.92	1.36	4.27	2.84	5.31	5.87	3.19	11.81	3.79	1.27	1.72	3.49	50.84
1842–1843.....	3.66	1.44	2.54	4.42	4.72	2.05	1.69	4.54	9.26	4.86	3.22	4.18	46.58
1879–1880.....	4.69	1.51	2.43	3.53	2.43	0.54	1.67	7.74	5.09	1.10	1.74	1.75	34.22
1880–1881.....	4.05	3.66	4.76	3.83	0.61	2.71	3.87	0.96	1.18	0.94	3.04	2.02	31.63

The dryness of these periods is not revealed in the yearly totals, but has been shown by our previous analysis. The question of which was the more trying period upon stream-flow must be left for a later chapter. We regard these records as typical of such extreme dry years as may be looked for once in fifty years, the choice of the driest period lying between the New York record of 1842–1843 and the Philadelphia record of 1880–1881. Our conclusion is that the driest year is likely to be as dry in one place as another, and that these types apply to all parts of the State.

Having fixed the driest year, our next quest must be for an ordinary dry year, such as is likely to occur as often as once in seven years. Consulting our diagram of annual precipitation, we find that at Philadelphia a yearly precipitation as low as 35.00 inches has been reached eight times in the fifty-six years of cotemporaneous records there and at New York, and that an annual fall of 37.00 inches occurs with about the same frequency in the New York series. These are each about 80 per cent. of the annual mean, and we should expect the ordinary dry year to vary with the mean rainfall. In order to determine the distribution through an ordinary dry year, we have charted the rainfall for five dry years. The usual method would be to take years of about the above annual precipitation and average the months, but Plate II. shows this to be inexpedient, as it will tend to cover up the extremes peculiar to such years, and produce a year unlike what is ever likely to occur. In order to get the natural sequence of monthly rainfall, we have preferred to adopt from these typical years one which is a fair type of all. Such an one is the year 1878. It embodies all the important features of these years in such a way as to make an excellent type, excepting in the preceding December rainfall, which in all the other cases is heavier. This we have corrected, and have resulting a satisfactory natural type of the ordinary dry year, shown, together with the average year for Philadelphia and the driest year for all the State, in Plate II. The average annual rainfall for our different water-sheds, given in Table No. 2, ranges from 44.09 to 49.10 inches. We give, in Table No. 5, the ordinary dry year corresponding to the various annual rainfalls:

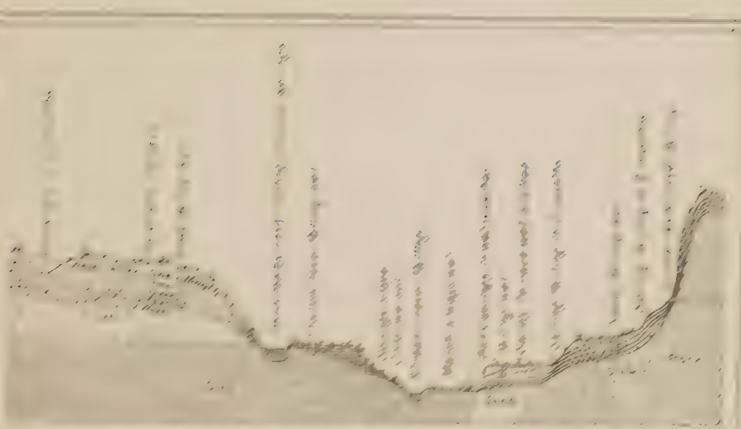
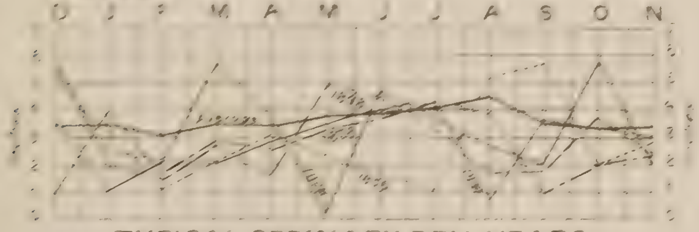


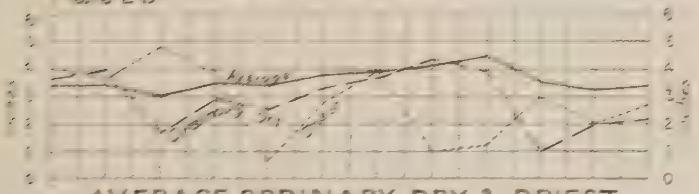
PLATE 3. DIAGRAM ILLUSTRATING GROUND WATER PHENOMENA DURING DROUGHT

Plate 2a.



TYPICAL ORDINARY DRY YEARS, PHILADELPHIA.

Plate 2b.



AVERAGE. ORDINARY DRY & DRIEST YEARS. PHILADELPHIA.

TABLE No. 5.

Precipitation for Ordinary Dry Years.

For average annual precipitation in inches of.	December.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	Year.
44.00...............	3.86	3.94	1.64	2.89	2.55	3.29	3.66	4.35	3.83	0.96	2.04	2.19	35.20
45.00...............	3.95	4.04	1.67	2.95	2.60	3.36	3.73	4.47	3.93	0.99	2.09	2.22	36.00
46.00...............	4.04	4.12	1.71	3.02	2.67	3.44	3.82	4.55	4.00	1.01	2.14	2.28	36.80
47.00...............	4.13	4.21	1.75	3.08	2.73	3.52	3.90	4.64	4.09	1.03	2.18	2.34	37.60
48.00...............	4.21	4.30	1.78	3.15	2.78	3.59	3.98	4.74	4.17	1.10	2.22	2.38	38.40
49.00...............	4.29	4.38	1.82	3.21	2.83	3.65	4.07	4.84	4.26	1.16	2.26	2.43	39.20

These ordinary dry years will apply to our various water-sheds according to their average annual rainfall, and without needing further correction for slight differences in this average. These, as we have stated, may be expected to occur once in seven years. Our driest year previously given is, therefore, one which occurs for seven of these ordinary dry years, or once in fifty years, as before stated.

It will be noticed that our average year is a purely artificial year, a mathematical conception which in reality never has occurred. Nevertheless, such a year is useful as giving an epitome of the experience of fifty-seven years, and is in accord with usual practice.

Our ordinary dry and driest years are, on the contrary, based upon natural years, such as have really occurred, and may be expected to occur again at the intervals which we have indicated, although probably not with the same order of months as here given.

The following records of precipitation are selected from the longest series in order to present the different conditions likely to occur during such periods. It is not safe to draw many conclusions from series covering less than a quarter of a century, and indeed one such year of excessive rainfall as those of 1837, 1847, 1865, 1868 or 1889, in the New York series, will add an inch to the mean of twenty years, or one such monthly rainfall as that of September, 1882, will add over half an inch to the monthly mean of such a series. The teaching of these incidents is to so far as possible avoid averages in matters of precipitation and stream-flow.

TABLE No. 6.

Precipitation at New York City.

FROM REPORTS OF DR. DANIEL DRAPER, AND INFORMATION FURNISHED BY THE UNITED STATES WEATHER BUREAU.

Rain and Melted Snow. In Inches.

YEAR.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.
1836	1.09	2.01	1.31	2.66	0.63	6.46	1.44	2.37	3.40	2.00	1.90	2.30	27.57
1837	2.70	3.70	8.20	7.50	9.50	8.50	5.90	6.30	2.10	2.11	2.90	6.10	65.51
1838	3.93	3.70	4.10	2.50	3.99	3.12	1.83	4.79	4.96	3.64	3.10	2.24	41.90
1839	0.69	2.05	2.46	3.35	8.37	4.94	1.35	4.92	3.59	1.45	2.19	7.61	42.97
1840	1.84	1.84	2.92	2.03	2.39	2.40	1.80	4.25	1.84	4.59	2.90	1.00	29.80
1841	5.30	0.80	2.35	3.93	3.95	4.65	4.90	2.50	2.90	4.40	3.70	2.70	42.08
1842	1.07	2.85	1.25	3.60	3.60	3.30	3.80	2.81	2.10	4.30	1.80	3.50	33.98
1843	1.00	2.31	2.13	2.14	1.00	0.76	1.64	15.26	3.06	5.91	2.82	3.34	41.37
1844	2.66	1.03	4.50	0.55	3.41	2.37	6.00	2.73	4.50	4.08	1.73	2.82	36.38
1845	4.87	3.22	3.33	1.22	1.75	3.70	1.75	3.21	2.62	2.50	3.40	2.51	34.08
1846	3.92	3.01	3.82	4.01	9.70	1.39	6.01	3.88	0.48	1.34	8.36	2.99	48.91
1847	4.62	5.74	8.48	1.53	2.18	6.78	1.62	6.93	12.20	2.13	6.29	6.35	64.85
1848	1.75	1.68	2.23	1.16	7.28	4.56	2.64	1.41	1.87	6.61	1.59	4.02	36.80
1849	0.61	2.26	4.87	0.62	3.47	0.78	1.43	4.63	1.55	5.63	1.88	4.01	31.74
1850	5.57	2.64	4.64	2.72	9.20	3.07	3.92	7.21	4.71	3.16	2.33	5.36	54.53
1851	1.46	4.50	1.70	6.94	4.73	0.90	4.72	3.47	1.26	2.95	4.53	3.72	40.88
1852	2.92	3.08	4.43	4.74	2.24	2.11	3.25	6.20	2.29	2.06	6.07	4.45	43.84
1853	4.14	4.98	2.03	3.32	5.80	4.80	4.40	5.50	5.49	3.90	6.80	1.04	52.20
1854	2.60	4.00	0.70	8.80	7.70	2.20	1.90	1.03	1.90	1.80	3.95	8.60	45.18
1855	4.77	5.12	2.83	2.86	4.90	5.83	5.06	2.90	1.51	7.37	3.00	6.86	53.01
1856	3.98	0.66	2.08	2.72	4.78	3.58	2.79	6.73	5.05	1.18	2.50	4.45	40.50
1857	4.99	1.69	2.32	9.05	6.72	5.43	6.13	3.90	4.26	1.67	1.30	6.42	53.88
1858	3.80	3.30	1.47	4.83	6.06	6.42	4.32	3.15	3.50	4.19	5.99	4.90	51.87
1859	5.78	5.59	8.21	5.10	1.57	4.60	4.76	4.12	6.45	1.75	3.37	4.42	55.72
1860	2.52	3.28	1.60	3.21	4.54	1.43	3.33	3.85	6.24	3.55	7.57	4.05	45.17
1861	4.81	2.45	5.78	5.62	6.03	4.24	2.89	5.52	4.03	3.46	8.09	1.73	54.65
1862	5.60	4.17	4.54	2.14	3.84	9.03	5.85	2.15	2.25	6.86	5.63	1.91	53.97
1863	5.45	7.04	5.77	5.69	4.58	1.43	8.60	4.59	1.05	4.09	3.88	4.86	57.03
1864	2.92	2.04	2.15	3.28	5.23	4.41	3.20	5.19	5.45	2.68	5.16	5.90	47.61
1865	3.40	4.06	8.32	4.14	5.56	10.42	5.21	2.23	4.21	4.94	4.19	6.30	62.98
1866	2.56	10.09	2.28	4.09	4.46	4.38	1.67	4.81	4.85	5.28	3.84	3.92	52.23
1867	2.54	5.53	4.09	2.47	5.70	10.18	5.76	7.68	0.78	5.12	2.25	2.56	54.66
1868	4.00	2.31	3.69	6.42	7.19	4.66	6.44	8.31	9.60	2.01	5.13	4.27	64.03
1869	2.53	6.87	4.61	1.39	4.15	4.40	3.15	1.76	2.81	6.48	2.30	5.02	45.47
1870	4.41	2.83	3.33	5.11	1.83	2.82	3.76	3.07	2.52	4.97	2.42	2.18	39.25
1871	2.07	2.72	5.54	3.03	4.04	7.05	5.57	5.60	2.34	7.50	3.56	2.24	51.26
1872	1.88	1.29	3.74	2.29	2.68	2.93	7.83	6.29	2.95	3.35	4.08	3.18	42.49
1873	5.34	3.80	2.09	4.16	3.69	1.28	4.61	9.56	3.14	2.73	4.63	2.96	47.99
1874	5.33	2.04	2.12	8.77	2.24	2.78	5.06	2.43	8.24	1.70	2.30	2.82	45.83
1875	3.17	2.62	3.48	3.08	1.33	2.72	4.89	8.97	1.89	2.85	3.78	2.12	40.90
1876	0.94	4.81	8.79	3.06	3.03	2.66	3.65	2.28	5.28	1.42	3.31	2.54	41.77
1877	2.62	1.24	5.56	2.73	0.95	2.80	5.73	2.77	1.33	8.14	5.63	0.68	40.18
1878	4.46	3.75	3.27	1.97	3.19	3.08	4.62	7.97	4.05	2.43	4.73	5.14	48.66
1879	2.63	2.02	3.41	4.33	2.02	3.15	3.58	7.95	2.37	0.43	2.20	4.94	39.03

Precipitation at New York City—Continued.

YEAR.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.
1880..........	2.02	2.12	4.66	2.90	0.62	1.14	8.53	5.26	1.85	2.81	2.46	2.27	36.64
1881..........	4.80	4.93	5.81	0.95	3.20	5.35	1.25	0.86	0.97	1.60	2.36	4.18	36.26
1882..........	6.15	4.36	2.32	2.15	4.21	2.82	2.75	1.63	14.51	1.69	1.80	2.22	46.61
1883..........	3.22	4.58	1.63	3.82	3.03	4.00	3.37	2.29	3.57	4.27	1.65	3.40	38.83
1884..........	6.07	5.09	4.43	2.66	4.35	4.16	6.14	8.56	0.15	3.63	3.44	6.66	55.34
1885..........	3.50	6.09	1.19	2.44	2.22	1.86	3.04	7.70	0.72	5.62	5.05	2.69	42.12
1886..........	5.02	5.90	3.54	4.95	6.53	3.01	2.57	1.18	1.79	3.90	4.61	3.73	46.73
1887..........	4.19	5.26	3.51	3.67	0 99	7.70	6.75	3.66	2.30	2.36	2.04	4.20	46.63
1888..........	5.14	4.30	5.64	3.57	4.87	1.68	1.27	6.35	7.40	4.14	4.81	4.05	52.95
1889..........	5.38	3.07	4.09	5.90	3.25	2.38	9.63	3.39	7.43	2.53	9.82	1.81	58.68
1890..........	2.95	3.86	6.67	2.58	3.11	4.19	3.96	4.06	8.21	6.46	0.82	5.34	52.21
1891..........	5.73	4.69	4.22	2.37	3.10	1.18	4.11	5.87	2.12	2.69	2.06	3.30	41.44
1892..........	5.61	1.27	4.62	2.36	4.30	2.97	2.45	3.90	0.87	0.63	8.28	1.64	38.90
Average, 57 years...	3.60	3.55	3.84	3.60	4.12	3.88	4.11	4.70	3.70	3.39	3.83	3.80	46.12

TABLE No. 7.

Precipitation at Newark.

Rain and Melted Snow. In Inches.

YEAR.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.
1843.........	......	......	....	....	0.85	1.59	2.29	22.48	3.61	5.91	3.92	4.14	....
1844.........	4.99	1.64	4.78	0.39	3.55	2.56	5.82	2.08	2.97	5.52	2.04	3.88	40.21
1845.........	3.37	4.21	3.76	1.27	2.16	3.4	2.17	4.8	2.46	2.25	2.88	3.73	36.47
1846.........	5.12	4.16	3.42	3.26	8.75	2.17	4.73	4.11	0.55	2.81	8.75	3.74	51.57
1847.........	4.65	6.08	4.14	0.85	3.16	6.25	3.30	2 89	11.3	3.46	2.84	5.91	54.83
1848.........	1.82	1.82	2.39	1.34	5.98	6.01	2.06	0.96	2.19	4.97	2.72	4.52	36.78
1849.........	0.64	2.69	4.85	0.91	4.24	1.09	2.36	8.09	1.6	6.93	2.18	4.47	40.05
1850.........	5.01	3.06	4.17	3.03	7.44	3.53	7.42	4.73	4.40	1.73	1.52	5.11	51.14
1851.........	2.01	4.5	3.97	6.09	3.93	1.10	6.44	1.52	0.62	3.66	4.61	1.93	40.38
1852.........	2.92	2.21	4.80	5.22	2.67	1.72	2.54	4.16	1.74	2.17	5.85	7.54	43.54
1853.........	3.09	5.22	3.14	3.02	4.67	3.66	3.25	11.22	5.03	5.08	3.67	1.29	52.34
1854.........	1.79	5.02	0.98	11.37	4.17	2.1	3.58	1.12	3.96	2.44	4.31	2.64	43.47
1855.........	4.03	3.47	1.87	2.47	2.37	4.52	4.47	4.16	2.25	5.26	2.89	6.5	44.26
1856.........	3.37	1.25	2.	2.57	4.32	3.12	1.41	5.7	2.67	1.4	2.79	3.48	34.07
1857.........	3.83	1.5	1.99	7.16	6.03	5.34	5.08	4.02	3.81	3.95	0.87	5.79	49.36
1858.........	3.41	2.49	1.01	3.85	5.00	4.65	2.99	4.21	1.41	3.01	4.79	4.26	41.07
1859.........	6.06	3.8	6.88	5.31	2.25	3.94	4.03	6.26	6.99	2.55	3.78	5.2	57.05
1860.........	2.32	2.71	1.23	2.51	5.	1.81	2.72	6.24	5.65	2.83	6.72	3.42	43.15

Precipitation at Newark—Continued.

YEAR.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.
1861	4.46	1.89	4.91	4.92	5.19	2.6	1.12	3.97	3.26	2.87	6.42	1.99	43.60
1862	5.42	3.69	4.00	3.21	3.05	6.60	3.02	3.01	2.12	4.27	4.45	1.85	44.69
1863	4.27	4.25	5.25	5.83	4.49	1.04	5.95	4.97	1.3	3.44	2.61	4.57	48.
1864	1.73	0.83	3.14	3.67	5.28	1.86	2.67	3.21	4.68	2.68	3.95	4.76	38.45
1865	4.09	4.57	4.89	3.34	5.73	3.49	6.73	3.94	3.21	4.68	3.3	4.39	52.35
1866	1.74	5.07	1.82	2.82	4.4	2.51	1.84	5.34	5.47	3.97	2.09	2.91	39.98
1867	1.61	5.64	4.40	2.57	6.55	9.75	3.75	10.62	1.23	4.62	1.95	2.04	54.73
1868	3.27	1.62	2.17	5.26	6.92	5.90	8.53	4.76	8.95	1.25	4.38	3.84	56.85
1869	3.42	5.06	4.67	1.15	4.67	5.84	3.69	1.56	2.54	6.82	3.08	5.44	47.93
1870	4.73	4.26	4.56	7.	1.99	3.13	6.96	3.10	2.79	4.75	2.46	2.19	47.91
1871	3.03	3.05	4.99	3.68	3.95	7.11	4.14	5.31	1.99	6.03	3.99	2.17	49.44
1872	1.85	1.77	3.88	3.75	3.07	4.27	8.94	6.63	3.24	3.11	4.17	3.79	48.46
1873	5.82	3.88	2.76	5.84	3.75	1.72	6.61	7.77	3.55	3.74	4.67	2.47	52.58
1874	5.67	3.17	2.13	8.72	2.75	3.58	4.23	2.79	9.05	2.43	2.86	2.81	50.19
1875	3.31	2.4	3.82	3.14	1.59	2.34	5.98	10.22	1.93	2.87	4.36	2.61	44.56
1876	1.2	5.36	10.	3.30	3.05	1.58	3.06	2.45	7.51	1.26	4.04	2.51	45.32
1877	3.06	1.65	6.07	3.13	1.01	4.17	5.98	7.73	1.47	7.73	6.92	0.92	49.84
1878	6.52	4.96	3.64	1.73	4.20	2.45	4.33	8.06	2.53	2.83	4.57	7.47	53.29
1879	2.89	2.53	3.74	4.76	2.18	3.03	5.05	9.12	3.75	0.32	1.94	5.33	44.64
1880	2.59	2.83	4.9	3.31	0.76	1.18	7.46	4.68	2.48	2.1	2.37	2.68	37.34
1881	5.05	4.64	6.83	1.71	2.91	5.04	1.34	0.28	0.87	2.73	3.07	4.53	39.00
1882	5.80	4.73	3.19	2.01	5.69	2.08	3.52	1.31	17.66	2.00	1.77	1.94	51.70
1883	3.71	4.92	2.00	4.65	3.35	4.47	2.76	2.46	4.74	5.36	1.43	2.72	42.57
1884	5.16	4.14	5.63	2.66	2.03	4.95	5.28	5.39	0.25	3.52	2.92	5.90	47.83
1885	3.33	5.85	1.43	2.03	3.03	1.39	3.11	5.98	5.10	4.47	4.77	3.10	43.59
1886	4.96	4.67	3.95	4.17	7.13	3.19	4.78	1.57	1.63	2.91	4.86	4.25	48.07
1887	3.63	5.43	3.62	3.12	5.80	7.00	7.05	3.23	2.30	2.53	2.08	4.82	50.61
1888	5.86	4.29	6.08	4.05	6.33	2.70	2.06	7.08	6.21	4.04	4.90	3.27	56.87
1889	6.04	2.86	3.31	6.24	2.43	3.04	14.60	4.57	8.23	2.42	8.87	2.38	64.99
1890	2.54	4.27	6.61	2.10	4.19	4.44	5.40	5.20	5.13	6.49	0.78	3.71	50.86
1891	7.11	4.67	4.61	2.11	2.95	2.02	6.73	4.61	2.53	2.54	2.44	4.08	46.40
1892	5.63	1.62	3.54	3.53	4.56	4.82	3.41	3.87	1.94	0.64	7.27	1.69	42.52
Average, 50 years													46.68

TABLE No. 8.

Precipitation at Lake Hopatcong.

Rain and Melted Snow. In Inches.

YEAR.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.
1846	3.88	0.42	6.34	2.03	4.88	3.64	7.17	7.78	0.87	3.23	5.76	4.12	50.12
1847	4.26	5.84	4.18	0.25	2.76	3.94	5.35	2.59	10.84	3.50	1.61	7.30	52.42
1848	2.02	1.44	2.49	1.95	5.90	4.04	3.14	0.50	2.02	3.89	4.88	6.09	38.36
1849	0.48	1.34	3.90	2.40	5.25	1.33	1.37	5.66	0.50	9.47	2.77	4.75	39.22
1850	3.67	4.66	3.56	3.37	6.56	1.81	7.91	5.75	7.58	2.68	1.96	5.10	54.61
1851	0.82	4.71	2.27	6.59	4.37	1.36	3.85	1 38	1.49	4.41	3.31	3.00	37.56
1852	2.91	3.05	3.48	5.25	2.36	2.17	5.17	6.15	2.05	2.82	6.12	5.54	47.07
1853	1.75	4.01	2.86	3.84	6.01	4.06	5.72	5.21	2.85	6.13	4.42	1.68	48.54
1854	2.71	4.07	1.07	7.35	5.36	3.85	5.17	1.55	5.80	2.13	3.95	2.10	45.11
1855	3.43	0.40	1.55	2.67	6.04	7.64	7.51	2.02	1.86	9.94	3.03	7.24	53.33
1856	1.45	0.52	0.82	2.74	4.14	4.02	0.90	8.55	6.03	1.42	1.97	5.10	37.66
1857	1.50	2.20	1.62	6.66	6.22	4.63	4.75	4.69	2.67	4.56	2.24	5.66	47.40
1858	2.43	1.84	0.40	3.21	6.37	4.15	4.24	4.21	1.96	2.72	4.05	3.83	39.41
1859	5.15	2.87	7.54	5.03	2.10	3.99	3.25	6.62	8.73	1.87	4.09	2.09	53.33
1860	2.12	2.78	0.91	2.17	4.56	2.07	2.79	6.37	2.79	2.04	6.37	1.90	36.87
1861	2.32	1.33	3.66	6.10	3.03	1.72	2.01	3.68	5.05	1.65	4.64	0.75	35.94
1862	3.37	1.50	2.48	2.69	1.89	6.10	2.84	1.97	2.08	3.65	2.97	0.75	32.19
1863	2.62	2.90	3.64	2.90	2.52	0.93	3.91	3.07	2.11	3.90	2.66	3.55	34.71
1864	0.98	0.46	2.25	3.31	7 69	1.32	1.66	5.01	3.17	1.36	2.68	1.61	31.50
1865	2.42	1.99	4.23	3.51	5.17	3.62	5.26	2.03	1.63	3.16	2.24	3.11	38.37
1866	0.61	4.54	0.60	2.13	2.49	3.63	1.92	3.05	4.44	2.21	2.41	2.03	30.06
1867	0.63	1.92	1.88	3.11	6.91	7.29	3.53	10.70	0.35	2.98	1.68	0.60	41.58
1868	1.97	0.97	0.80	2.46	5.33	7.24	3.39	3.37	11.44	1.04	3.90	1.02	42.93
1869	3.43	2.78	4.41	1.51	4.29	3.37	2.10	1.58	7.12	9.82	8.46	4.03	52.90
Averages	2.37	2.44	2.79	3.47	4.67	3.66	3.95	4.31	3.98	3.77	3.67	3.46	42.55

The above record was kept by Wm. H. Talcott, engineer and superintendent of Morris Canal Company.

TABLE No. 9.

Precipitation at New Brunswick.

FROM RECORDS BY DR. GEO. H. COOK AND P. V. SPADER, ESQ.

Rain and Melted Snow. In Inches.

YEAR.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.
1854..........	2.00	4.82	1.16	9.22	4.12	3.65	3.63	1.48	2.67	1.70	3.21	2.39	40.05
1855..........	3.05	2.51	1.80	2.21	3.54	4.83	3.17	2.48	2.66	3.84	2.48	5.81	38.38
1856..........	3.73	0.79	3.01	3.76	3.24	1.83	1.92	6.03	4.71	0.90	2.98	3.17	36.07
1857..........	3.48	1.18	0.97	6.24	5.10	3.71	4.20	6.16	3.35	3.91	......	5.93	44.23
1858..........	3.30	1.91	1.90	4.01	4.80	0.24	2.85	3.00	1.54	2.01	3.56	4.23	33.35
1859..........	4.43	3.23	6.04	4.56	1.82	4.68	3.47	4.88	7.20	1.81	3.58	3.97	49.67
1860..........	2.61	1.60	0.80	1.85	5.63	2.28	2.72	11.52	4.32	3.02	6.27	3.44	46.06
1861..........	3.81	1.92	3.50	5.05	5.52	2.52	1.26	3.04	2.41	2.59	8.77	1.90	42.29
1862..........	5.37	2.63	3.70	3.93	2.33	7.10	5.80	1.29	3.10	5.21	5.61	1.22	47.29
1863..........	3.84	4.25	5.35	6.60	3.77	2.46	10.59	4.08	1.13	3.26	2.42	4.75	52.50
1864..........	2.73	0.84	4.19	4.24	6.08	2.12	1.65	3.37	4.67	1.71	5.04	4.20	40.84
1865..........	3.54	4.73	4.26	3.99	6.24	2.31	7.10	3.21	2.72	4.62	2.57	5.94	51.23
1866..........	1.74	5.04	2.24	3.20	4.50	3.10	3.22	7.80	5.47	3.88	2.82	3.58	46.59
1867..........	1.97	6.01	4.76	2.16	6.45	11.42	5.50	9.20	0.44	4.60	2.06	1.99	56.56
1868..........	3.88	2.20	2.05	4.99	7.57	6.41	6.26	3.55	7.59	1.34	4.94	3.32	54.10
1869..........	3.49	5.84	4.87	1.62	5.18	5.57	3.61	0.70	2.34	8.53	3.76	4.86	50.37
1870..........	4.53	4.88	4.36	5.87	3.15	5.91	4.66	6.70	3.08	5.60	1.91	2.34	52.99
1871..........	4.12	3.77	5.09	3.22	3.50	5.90	8.91	9.25	2.39	5.51	4.19	2.31	58.16
1872..........	1.70	1.66	4.19	2.15	2.45	3.85	8.97	7.12	3.01	4.09	4.04	4.70	47.93
1873..........	5.33	4.72	2.39	5.12	4.26	3.88	9.47	10.79	3.59	4.65	4.36	2.40	60.96
1874..........	4.33	2.90	2.06	8.25	1.85	3.05	4.02	2.35	8.61	2.66	2.44	2.78	45.30
1875..........	3.64	3.81	4.30	2.84	1.77	4.56	3.94	8.08	2.19	2.62	4.37	2.77	44.89
1876.....	1.21	5.07	7.51	2.59	2.93	1.91	1.70	1.08	5.82	1.54	5.45	2.62	39.43
1877..........	3.70	1.68	6.35	3.38	0.99	4.49	4.60	4.85	1.94	6.83	7.29	1.19	47.29
1878..........	4.01	3.56	3.39	1.38	5.71	4.34	6.23	3.02	2.22	3.42	3.65	5.43	46.36
1879..........	2.81	2.06	3.66	4.90	2.85	5.10	5.16	7.30	2.00	0.27	2.13	5.34	43.58
1880..........	2.20	2.63	4.87	2.36	0.67	1.85	8.83	4.08	1.81	2.10	2.45	3.32	37.17
1881..........	6.22	5.11	5.57	0.55	2.30	5.88	0.86	1.73	0 94	2.25	3.13	3.92	38.46
1882..........	5.49	4.24	2.62	2.85	5.29	1.48	3.04	3.20	15.52	1.42	1.60	1.91	48.66
1883..........	3.71	4.67	1.96	4.03	2.82	5.24	3.44	4.40	3.35	4.29	1.49	3.61	43.01
1884..........	5.63	5.23	4.23	2.20	3.17	5.34	4.80	5.03	0.37	3.16	3.60	5.63	48.44
1885..........	3.72	4.93	1.08	2.14	2.01	1.67	4.29	5.30	0.80	4.00	4.04	2.72	36.70
1886..........	4.16	4.94	3.95	3.57	5.30	4.06	4.61	1.90	1.50	2.48	4.81	3.73	45.01
1887..........	4.74	6.15	3.59	3.31	1.14	6.28	6.20	7.34	3.07	2.44	2.30	5.28	51.84
1888..........	5.22	3.90	5.43	4.68	5.25	3.51	2.66	5.93	8.17	5.55	4.29	4.41	59.00
1889..........	6.43	2.38	3.23	4.97	4.19	3.38	10.45	5.01	7.83	3.13	8.49	1.81	61.30
1890..........	2.76	4.15	6.92	2.51	3.93	3.90	7.27	5.87	5.14	8.30	0.97	4.03	55.75
1881..........	7.70	4.86	5.83	1.75	3.20	1.62	3.34	6.58	1.76	3.29	2.18	4.55	46.66
1892..........	6.09	1.65	4.71	2.56	4.71	2.90	3.13	3.48	1.77	0.54	7.75	1.79	41.08
Averages, 39 years..	3.91	3.55	3.79	3.71	3.83	3.96	4.81	4.93	3.67	3.41	3.77	3.57	46.91

TABLE No. 10.

Precipitation at Vineland.

Rain and Melted Snow. In Inches.

YEAR.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.
1868............	3.73	4.05	4.82	5.02	6.69	3.95	3.00	6.02	5.45	1.07	7.24	4.40	55.44
1869............	4.15	4.44	3.70	2.56	4.38	4.66	2 80	1.27	6.62	6.75	4.42	4.87	50.62
1870............	3.35	2.87	3.10	5.07	8.45	4.32	3.03	8.15	2.82	3.05	2.80	2.32	49.33
1871............	6.23	3.75	6.33	2.40	3.00	5.03	9.82	3.02	1.80	3.35	5.18	3.05	52.96
1872............	2.33	2.85	4.50	2.17	2.21	2.59	4.42	4 50	5.53	5.50	3.64	4.68	44.92
1873............	6.31	6.25	2.25	3.00	3.58	0.60	6.18	7.75	6.11	6.04	4.27	2.60	54.94
1874............	4.90	3.43	1.64	8.32	1.49	3.25	2.41	2.48	5.95	2.25	2.93	3.32	42.37
1875............	4.10	4.64	6.57	4.10	0.91	2.95	1.85	8.40	3.55	1.62	4.91	2.35	45.95
1876............	1.62	3.72	6.31	2.25	6.10	5.43	3.87	2.18	9.91	1.30	5.60	3.63	51.92
1877............	5.18	2.82	6.44	2.35	2.18	3.90	7.12	2.05	5.98	5.83	5.12	1.88	50.85
1878............	5.01	1.73	3.89	2.36	4.14	5.36	6.42	8.46	0.69	2.18	2.25	5.69	48.18
1879...........	3.75	2.38	3.36	3.46	0.77	4.90	3.04	10.63	3.35	1.14	2.75	6.27	45.80
1880............	2.82	2.26	6.35	2.60	2.00	3.05	8.63	6.35	2.94	2.75	4.44	7.52	51.71
1881............	6.81	5.61	5.27	1.30	3.53	4.57	2.96	0.65	2.35	3.12	3.08	3.23	42.48
1882............	6.45	5.41	4.31	2.19	5.19	1.36	2.23	9.29	12.35	1.77	0.99	2.47	54.01
1883............	6.12	6.46	2.93	3.95	1.80	3.71	0.51	2.00	4.98	7.06	1.87	5.16	46.55
1884............	10.96	6.77	6.59	3.33	1.99	1.96	3.85	2.63	0.47	0.80	2.81	6.53	48.69
1885............	3.67	3.79	0.91	2.07	3.38	1.31	1.29	5.11	0.60	5.83	4.00	3.47	35.43
1886............	4.27	5.94	3.81	2.52	4.85	2.28	6.47	4.52	1.24	2.88	3.80	3.76	46.34
1887............	3.13	3.94	2.56	4.07	2.36	6.25	8.70	2.81	5.19	2.44	2.03	4.31	47.79
1888............	4.46	2.52	7.41	2.00	5.48	1.19	3.54	3.96	3.28	5.06	3.51	1.27	43.68
1889............	....	......	......	......	......	......	......	....	....	......	......	......	....
1890............	....	......	......	......	......	......	......	....	....	......	......	......	....
1891............	6.10	5.85	7.05	2.54	2.79	3.62	8.91	7.18	1.08	3.23	1.79	4.51	54.65
1892............	4.40	1.89	5.28	3.75	3.78	1.83	5.54	5.65	1.27	0.33	......	......	....
Averages, 22 years....	4.78	4.06	4.58	3.19	3.52	3.39	4.65	5.00	4.06	3.28	3.61	3.97	48.39

TABLE No. 11.

Precipitation at Philadelphia, Pa.

FURNISHED BY THE UNITED STATES WEATHER BUREAU.

Rain and Melted Snow. In Inches.

YEAR.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.
1825.........	0.84	3.26	4.63	0.83	1.72	3.59	2.06	3.70	2.61	1.25	1.36	3.72	29.57
1826.........	1.11	2.13	5.80	3.87	0.19	4.65	3.68	2.75	2.00	5.83	1.85	1.28	35.14
1827.........	2.86	3.55	1.23	2.83	2.50	2.09	2.97	5.75	0.79	5.91	4.87	3.26	38.50
1828.........	2.05	2.75	3.35	3.82	3.49	2.69	5.33	1.51	4.62	1.39	6.71	0.26	37.97
1829.........	5.37	3.75	2.87	4.99	2.68	3.44	4.35	4.61	2.01	2.30	3.97	1.51	41.85
1830.........	1.63	2.06	4.12	1.81	3.75	5.99	4.07	3.87	2.93	4.31	5.35	5.18	45.07
1831.........	6.02	2.44	3.17	5.20	1.07	3.56	4.17	5.39	5.33	4.51	1.88	1.20	43.94
1832.........	4.58	2.66	1.90	2.98	5.40	1.55	2.62	5.69	1.40	3.41	2.59	5.09	39.87
1833.........	3.97	1.24	2.22	0.70	5.88	5.28	4.15	3.39	3.82	10.05	2.18	5.67	48.55
1834.........	2.49	2.22	2.02	2.83	3.52	3.99	4.35	0.62	3.57	3.29	3.01	2.33	34.24
1835.........	2.75	1.81	3.83	4.33	1.99	6.27	6.55	2.05	2.63	1.22	3.19	2.68	39.30
1836.........	7.62	2.99	1.75	3.47	2.28	7.31	2.91	1.97	1.82	3.59	3.34	3.61	42.66
1837.........	2.50	3.58	3.76	2.83	4.86	2.83	5.89	4.00	2.28	0.66	3.23	2.56	39.04
1838.........	2.20	2.19	3.17	3.59	3.58	6.60	2.38	2.78	9.52	4.90	3.35	1.04	45.30
1839.........	5.04	3.42	1.50	1.51	6.07	3.92	2.52	4.64	2.92	2.83	3.10	6.26	43.73
1840.........	1.84	3.01	2.63	6.83	2.69	5.95	4.54	5.55	2.50	5.73	2.49	3.65	47.41
1841.........	7.84	1.39	5.82	6.46	3.27	3.11	3.28	9.10	1.90	3.20	4.22	5.92	55.51
1842.........	1.36	4.27	2.84	5.31	5.87	3.19	11.81	3.79	1.27	1.72	3.49	3.66	48.58
1843.........	1.44	2.54	4.42	4.72	2.05	1.69	4.54	9.26	4.86	3.22	4.18	4.04	46.96
1844.........	4.05	1.45	4.43	1.35	3.09	3.35	5.28	2.40	4.03	5.02	2.95	2.75	40.15
1845.........	3.76	4.74	2.41	2.58	1.60	3.73	2.76	7.30	2.16	2.53	2.50	3.96	40.03
1846.........	4.63	3.33	4.60	2.11	3.44	3.30	4.60	4.27	0.25	2.44	7.97	3.44	44.38
1847.........	4.73	4.60	4.70	0.59	1.57	3.30	2.77	3.18	8.07	3.08	2.84	5.78	45.21
1848.........	2.03	1.44	2.76	1.54	4.90	4.43	3.28	1.71	1.80	3.75	2.34	5.01	34.99
1849.........	0.73	2.61	5.47	1.75	4.00	2.20	2.93	6.98	1.40	5.59	2.60	5.84	42.10
1850.........	4.77	2.87	4.75	2.67	6.50	2.03	5.97	8.33	7.73	1.09	3.32	4.51	54.54
1851.........	1.23	3.11	3.48	4.57	4.82	3.44	2.52	2.55	1.13	3.02	3.36	2.27	35.50
1852.........	2.01	2.71	4.27	6.44	3.03	4.03	4.06	4.40	1.29	2.27	6.06	5.17	45.74
1853.........	1.84	4.44	2.46	3.38	5.17	1.05	8.63	3.08	4.46	3.47	2.32	2.16	42.46
1854.........	2.32	4.20	1.63	8.14	7.30	3.44	3.84	0.92	4.88	1.92	3.46	3.18	45.23
1855.........	2.60	2.48	1.98	2.15	3.03	8.01	6.59	3.24	4.13	3.42	2.02	5.01	44.66
1856.........	3.37	1.13	2.04	3.15	2.33	1.68	1.13	5.18	5.70	1.30	2.89	3.62	33.52
1857.........	2.99	2.06	1.74	7.36	6.97	8.21	3.49	7.77	1.17	3.97	1.44	5.85	53.02
1858.........	2.46	1.95	0.86	4.79	5.25	4.36	1.23	4.48	1.29	1.79	4.86	5.46	38.96
1859.........	5.52	3.53	6.60	5.18	1.73	5.51	3.96	4.18	7.54	3.60	3.40	3.73	54.48
1860.........	3.18	2.61	1.76	3.73	3.80	3.30	1.17	8.28	5.30	5.59	6.53	3.65	48.90
1861.........	3.81	2.06	3.55	3.73	6.47	4.34	2.91	3.10	4.39	3.80	3.30	1.76	43.22
1862.........	4.50	3.89	3.25	4.48	2.19	5.55	4.42	2.07	4.29	3.63	3.83	2.48	44.58
1863.........	4.70	3.82	6.38	7.29	4.79	4.05	5.69	1.44	0.98	2.66	2.96	4.87	49.63
1864.........	1.86	0.82	4.34	4.02	8.80	2.12	2.97	1.65	6.23	1.57	3.70	4.16	42.24
1865.........	2.80	4.01	3.70	2.62	6.17	3.66	2.55	3.37	7.29	3.20	4.13	5.64	49.12
1866.........	2.89	6.64	2.04	2.92	4.63	3.39	2.51	2.57	7.46	3.54	1.47	3.52	43.58
1867.........	1.93	4.82	5.67	1.36	7.07	10.95	3.03	16.84	1.85	4.02	1.93	1.82	61.29
1868.........	2.26	2.59	3.80	5.35	7.42	2.74	2.64	3.07	7.01	3.35	3.23	3.48	46.94

Precipitation at Philadelphia, Pa.—Continued.

YEAR.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.
1869.........	3.37	4.12	5.36	2.26	3.71	5.21	2.30	0.70	3.10	4.38	4.35	4.35	43.21
1870.........	4 01	2.56	4.52	5.41	5.24	2.54	3.50	5.98	1.60	4.11	1.97	2.13	43.57
1871.........	2.85	2.48	5.77	1.98	2.92	4.51	6.17	5.58	0.65	3.89	4.09	1.57	42.48
1872	1.49	1.12	3.67	2.60	3.15	4.29	9.20	7.81	3.66	5.20	3.43	2.74	48.36
1873.........	5.84	4.75	2.05	3.51	5.83	0.90	5.00	11.49	3.63	5.80	5.10	1.38	55.28
1874.........	4.58	2.46	2.16	9.76	2.75	2.96	2.25	5.65	6.01	2.87	2.32	2.48	46.25
1875.........	2.83	3.20	3.10	2.83	1.36	4.13	3.63	6.42	2.53	1.42	5.40	3.37	40.22
1876.........	1.52	5.03	6.71	2.16	4.45	2.29	5.71	0.98	8.77	1.06	7.31	1.40	47.39
1877.........	2.62	0.84	3.40	2.66	1.10	5.22	5.33	0.66	2.74	6.52	5.14	0.83	37.26
1878.........	3.94	1.64	2.89	2.55	3.29	3.66	4.35	3.83	0.96	2.04	2.19	3.19	34.53
1879.........	2.73	1.19	2.28	4.21	1.22	6.77	3.62	7.13	1.12	0 41	1.38	4.69	36.75
1880.........	1.51	2.43	3.53	2.43	0.54	1.67	7.74	5.09	1.10	1.74	1.75	4.05	33.58
1881.........	3.66	4.76	3.83	0.61	2.71	3.87	0.96	1.18	0.94	3.04	2.02	2.63	30.21
1882.........	4.57	4.22	3.57	2.12	5.06	1.90	1.37	6.40	12.09	1.32	0.99	1.97	45.58
1883.........	4.13	5.04	2.02	2.44	1.91	5.91	1.78	3.40	4.24	4.20	1.34	2.76	39.17
1884.........	5.46	5.70	4.70	1.63	3.39	3.00	3.83	4.30	0.20	1.54	2.31	3.28	39.54
1885.........	2.92	2.79	0.69	2.54	3.76	0.74	2.39	6.80	1.17	3.33	3.35	2.87	33.35
1886.........	3.69	4.62	3.17	2.70	4.50	2.86	4.23	1.38	1.20	1.89	3.91	3.09	37.24
1887.........	3.23	3.43	2.59	2.00	0.62	6.81	7.14	2.31	4.92	1.68	1.38	5.06	42.17
1888.........	4.30	2.57	5.42	2.10	3.46	1.09	3.38	5.86	5.73	3.23	3.77	3.15	44.06
1889.........	3.75	2.00	2.58	3.17	4.32	3.39	8.29	7.07	4.66	3.76	6.76	0.85	50.60
1890.........	1.83	3.39	4.61	2.28	2.96	1.30	4.03	3.36	2.31	4.82	0.80	2.33	34.02
1891.........	3.65	4 71	4.42	2.34	1.74	2.51	4.65	4.22	1.90	2.57	1.70	3.78	38.19
1892.........	4.48	0.98	4.32	2.03	5.12	1.98	2.97	2.74	2.06	0.30	5.71	2.09	34.78
Averages, 68 years..	3.45	3.08	3.53	3.43	3.78	3.86	4.12	4.50	3.54	3.28	3.39	3.41	43.35

Snowfall has an important bearing upon stream-flow in winter, as when it is heavy the usual result is comparatively light flow in the early winter and heavy floods in the spring. In Climatology (page 377, Final Report, Vol. I.) it is stated that the average annual fall in the Highlands and Kittatinny valley region is probably about 60 inches. From this it ranges down to comparatively an insignificant amount in the region of the Atlantic coast streams. The average depth at Lambertville from 1839 to 1859 was 29.5 inches, at Newark from 1843 to 1859 inclusive, it was 43.5 inches. The following table gives such definite data as we have at hand:

TABLE No. 12.

Depth of Snow. In Inches.

WINTER OF	RECEIVING RESERVOIR, NEW YORK.							NEWARK.
	November.	December.	January.	February.	March.	April.	Total.	Total.
1843-1844	....	....	....	....	....	....	....	31
1844-1845	....	....	....	....	....	....	....	39
1845-1846	....	....	....	....	....	....	....	52
1846-1847	....	....	....	....	....	....	....	48
1848-1849	....	....	....	....	....	....	....	45
1849-1850	....	....	....	....	....	....	....	31
1850-1851	....	....	....	....	....	....	....	25
1851-1852	....	....	....	....	....	....	....	63
1852-1853	....	....	....	....	....	....	....	25
1853-1854	....	....	....	....	....	....	....	71
1854-1855	....	....	....	....	....	....	....	45
1855-1856	....	....	....	....	....	....	....	65
1856-1857	....	....	....	....	....	....	....	52
1857-1858	....	....	....	....	....	....	....	28
1858-1859	....	....	....	....	....	....	....	47
1859-1860	....	....	....	....	....	....	....	51
1860-1861	....	....	....	....	....	....	....	48
1861-1862	....	....	....	....	....	....	....	52
1862-1863	....	....	....	....	....	....	....	50
1863-1864	....	....	....	....	....	....	....	22
1864-1865	....	....	6.5	8.75	0.25	....	....	48
1865-1866	....	10	8.75	7.25	2	....	28.00	35
1866-1867	....	3.25	27.25	13	12.25	....	55.75	62
1867-1868	....	12	25.75	15.25	26	7.75	86.75	75
1868-1869	....	8.50	7.5	11.5	3.75	....	31.25	22
1869-1870	....	6.75	3	9.5	11.25	....	30.50	18
1870-1871	....	5	21	18.25	....	2	46.25	37
1871-1872	0.5	7	2.75	4	4	0.75	19.00	16
1872-1873	4.25	24.75	12	16	1	....	58.00	63
1873-1874	1.5	7	6.25	16.5	2	....	33.00	36
1874-1875	....	11.5	12.75	5.75	17.5	12.5	60.00	43
1875-1876	....	3.5	....	10	2.5	....	16.00	23
1876-1877	0.75	11.5	18	....	7.75	....	36.00	35
1877-1878	....	....	0.25	6	....	....	6.25	14
1878-1879	....	2	14.5	15	....	....	21.50	35
1879-1880	2	6	3.5	1	10	....	22.50	29
1880-1881	2.75	12	12	8	3	....	37.75	....
1881	....	2	....	....	....	....	....	....
Averages	....	....	....	....	....	....	36.78	40.96

TABLE No. 13.

Depth of Snow, in Inches, at New Brunswick. Record of P. V. Spader.

WINTER OF	November.	December.	January.	February.	March.	April.	Total.
1861–1862.........	....	....	....	....	....	13	....
1862–1863.........	13	4	8	8	5	3	38.00
1863–1864.........	s	s	6.5	s	6.5	s	13.00
1864–1865.........	s	15	7.5	3	s	....	25.50
1865–1866.........	s	8	12.5	4	1.5	s	26.00
1866–1867.........	s	9	19.75	18	12.5	....	59.25
1867–1868.........	s	13	6.5	14	12	7.5	53.00
1868–1869.........	s	1	4	3	0.5	....	8.50
1869–1870.........	s	4	1	6	6	4.0	21.00
1870–1871.........	....	4.25	22	14	....	s	40.25
1871–1872.........	s	5	s	3	1.5	....	9.50
1872–1873.........	2.5	20	12	17.5	1	s	53.00
1873–1874.........	2	5	4	22	s	0.5	33.50
1874–1875.........	s	s	8	6.5	12.5	s	27.00
1875–1876.........	s	s	s	10	2	....	12.00
1876–1877.........	s	4	21.5	s	1.25	....	26.75
1877–1878.........	s	....	s	10	s	....	10.00
1878–1879.........	....	3.5	12	8.5	s	s	24.00
1879–1880.........	s	4	3.7	6	3	s	16.70
1880–1881.........	4	15	13.5	9	s	s	41.50
1881–1882.........	s	s	9	12	3	s	24.00
1882–1883.........	4	s	10	5	6.25	s	25.25
1883–1884.........	s	25	7.5	4	3	s	39.50
1884–1885.........	s	8.5	s	14.5	s	s	23.00
1885–1886.........	s	s	8	6	s	s	14.00
1886–1887.........	s	9	11.6	s	5	.25	21.35
1887–1888.........	....	9.5	3	.25	30	s	42.75
1888–1889.........	s	s	s	1.5	s	....	1.50
1889–1890.........	....	s	s	s	13	....	13.00
Average......	....	....	....	....	....	....	26.43

NOTE.—In this New Brunswick record, s denotes snow, but not of measurable depth, being often accompanied by rain.

The above records are concurrent from 1866 to 1880, or for a period of fifteen years. During this time the averages were at New York 36.38 inches, at Newark 36.20 inches, and at New Brunswick 28.03 inches annually. These probably give us a fair indication of the relative snowfalls at each station.

Using the 28-year record at Newark as the standard, and reducing the other stations to this, we have the following as the most probable average snowfall at each station: Newark, 41.00 inches; New York, 41.00 inches; New Brunswick, 31.75 inches; Lambertville, 27.80 inches annually.

In the Highlands I have observed six months between the first and the last snowfall of measurable amount, the last being May 6th. Snowfall may be considerable here in November and April. In the red sandstone belt, while snow usually falls in these months, it is insignificant in amount as a rule, while farther south it is scarcely seen at all. Ten inches of snow being generally equivalent to an inch of rain, it is apparent, from the above tables, that there is always a possibility that in northern New Jersey some three inches of December precipitation may be carried over in the form of snow or ice to augment the stream-flow of later months. Since all this is included in returns of precipitation for December, it follows that the division of stream-flow observations into calendar years may lead to serious errors when we come to compare with precipitation. If our year is made to begin December 1st, there is practically no such danger, and we shall see later on why this date has advantages which have led to its adoption as the beginning of the year in our studies of stream-flow.

The division of our records by months becomes necessary for convenient, practical application of the long series of valuable records of precipitation, which are the basis of our studies. The calendar months are unequal in length, consequently not well adapted to our purposes excepting for these reasons.

EVAPORATION.

It is not our intention to go exhaustively into the general subject of evaporation in this report. We must, however, in order to check our conclusions and be prepared for an intelligent comprehension of its importance in our studies, give a brief abstract of what has been observed as to the amount and monthly distribution of evaporation under different circumstances. We need nothing more than this, for by far the most useful and reliable data we can have of evaporation over extended areas, such as the water-sheds of our streams, we shall obtain from the results of stream-gaugings, which we present in the next chapter. We have measurements of evaporation from water-surfaces, but there is very little water-surface exposed on our water-sheds; so we have measurements of the amount taken up by various

LAKE HOPATCONG, LOOKING NORTHWARD.

kinds of vegetation, but our areas are of a mixed character and it is not always possible to apportion them properly among the various crops. The measurements of evaporation from the ground come the nearest to what we need, but few of these have been made with necessary precautions to secure exactly the same conditions which exist in nature. Nevertheless, these observations are very suggestive, and some of the results are here reproduced.

The following tables are copied from Mr. Fanning's valuable treatise on water-supply engineering:

TABLE No. 14.

Evaporation From Water at Emdrup, Denmark.

Latitude, 55° 41′ N.; Longitude, 12° 34′ E. from Greenwich.

YEAR.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Total.
	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
1849...........	1.1	0.3	1.8	2.5	4.1	5.8	4.7	4.0	2.6	1.1	0.9	0.6	29.5
1850...........	1.1	0.3	1.2	1.7	4.5	5.6	4.8	4.8	2.4	1.6	0.9	0.2	29.1
1851...........	0.5	0.4	0.7	1.7	4.2	4.8	5.7	5.1	2.7	1.5	0.6	0.5	28.4
1852...........	0.7	0.5	0.8	2.4	3.8	4.6	6.4	4.5	2.7	1.7	0.8	0.5	29.4
1853...........	0.5	0.1	0.7	1.0	4.1	6.2	5.1	4.2	2.8	1.1	0.6	0.5	26.9
1854...........	0.5	0.9	0.9	3.2	3.3	4.5	5.2	4.3	2.6	1.2	0.7	0.6	27.9
1855...........	1.0	1.1	0.5	1.2	2.6	4.1	4.7	4.1	2.8	1.4	0.9	0.7	25.1
1856...........	0.5	0.5	1.2	2.1	2.8	4.6	4.3	4.0	2.0	1.9	0.6	0.5	24.0
1857...........	0.7	0.6	0.6	1.4	4.1	6.6	5.9	4.3	3.2	1.4	0.7	0.4	29.9
1858...........	0.4	0.7	1.2	3.1	5.1	6.1	4.9	5.6	2.8	1.6	0.7	0.4	30.6
1859...........	0.3	0.5	0.7	1.9	4.3	5.8	5.3	3.8	1.8	1.0	0.7	0.3	26.4
Mean..........	0.7	0.5	0.9	2.0	3.7	5.4	5.2	4.4	2.6	1.3	0.7	0.5	27.9
Ratio	.301	.215	.387	.860	1.592	2.323	2.237	1.892	1.118	.559	.301	.215	......

MEAN EVAPORATION FROM SHORT GRASS, 1852 TO 1859, INCLUSIVE.

Mean..........	0.7	0.8	1.2	2.6	4.1	5.5	5.2	4.7	2.8	1.3	0.7	0.5	30.1

MEAN EVAPORATION FROM LONG GRASS, 1849 TO 1856, INCLUSIVE.

Mean..........	0.9	0.6	1.4	2.6	4.7	6.7	9.3	7.9	5.2	2.9	1.3	0.5	44.0

MEAN RAINFALL AT SAME STATION, 1848 TO 1859, INCLUSIVE.

Mean..........	1.5	1.7	1.0	1.6	1.5	2.2	2.4	2.4	2.0	2.3	1.8	1.5	21.9

TABLE No. 15.

Evaporation From Earth.

MEAN EVAPORATION FROM EARTH, AT BOLTON LE MOORS,* LANCASHIRE, ENGLAND, 1844 TO 1853, INCLUSIVE.

Latitude, 53° 30′ N.; Height above sea, 320 feet..

	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Total.
Mean........	0.64	0.95	1.59	2.59	4.38	3.84	4.02	3.06	2.02	1.28	0.81	0.47	25.65
Ratio	.299	.444	.739	1.212	2.049	1.796	1.887	1.431	.945	.599	.379	.220	....

* Beardmore's Hydrology, page 325.

MEAN RAINFALL AT SAME STATION, 1844 TO 1853, INCLUSIVE.

Mean........	4.63	4.03	2.25	2.22	2 23	4.07	4.32	4.77	3.79	5.07	4.64	3.94	45.96

TABLE No. 16.

MEAN EVAPORATION FROM EARTH, AT WHITEHAVEN, CUMBERLAND, ENGLAND, 1844 TO 1853, INCLUSIVE.

Latitude, 54° 30′ N.; Height above sea, 90 feet.

	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Total.
Mean.......	0.95	1.01	1.77	2.71	4.11	4.25	4.13	3.29	2.96	1.76	1.25	1.02	29.21
Ratio	.390	.415	.727	1.113	1.689	1.746	1.697	1.352	1.216	.723	.513	.419	....

MEAN RAINFALL AT SAME STATION, 1844 TO 1853.

Mean.......	5.1	3.4	2.5	2.2	1.9	3.1	4.3	4.3	3.1	5.3	4 5	3.8	43.5

The next table is a very instructive one, furnished by Desmond Fitz Gerald, C.E., in a paper on "Rainfall, Flow of Streams and Storage" (Transactions of the American Society of Civil Engineers, Vol. XVII., No. 3). The table is partially made up from a diagram, so that to a certain extent the figures are averages, but only when the observations were so near to a mean as to warrant such a course:

TABLE No. 17.

Evaporation from Water-Surface at Boston, Mass., in Inches—Sixteen Years.

	1876.	1877.	1878.	1879.	1880.	1875–1890 and 1881–1884.	1885.	1886.	1887.	1888.	1889.	1875-1890.	
												Total.	Mean.
January	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	15.36	0.96
February	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	16.80	1.05
March	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	27.20	1.70
April	2.98	2.98	2.98	2.98	2.98	2.98	2.98	3.12	3.07	2.78	2.84	47.57	2.97
May	4.45	4.05	4.14	5.89	5.22	4.45	3.77	4.45	4.83	3.35	4.57	71.42	4.46
June	5.44	5.68	5.26	5.32	6.46	5.55	7.01	5.25	5.05	5.98	3.94	88.69	5.54
July	7.50	4.82	6.04	6.41	5.82	5.98	7.09	5.59	5.96	5.57	5.04	95.72	5.98
August	6.21	4.40	4.33	5.23	5.34	5.50	7.41	5.80	6.20	5.81	4.25	87.98	5.50
September	3.48	4.08	4.04	3.80	4.04	4.20	5.13	4.55	4.57	3.91	3.08	65.88	4.12
October	3.12	2.51	3.52	2.99	2.79	3.11	2.79	4.13	3.61	3.27	3.13	50.52	3.46
November	0.66	2.23	2.23	2.23	2.60	2.23	2.23	2.69	3.00	2.71	1.98	35.94	2.25
December	1.51	1.51	1.51	1.51	1.51	1.51	1.51	1.51	1.51	1.51	1.51	24.16	1.51
Total	39.06	35.97	37.76	40.07	40 47	39.22	43.63	40.80	41.51	38.60	34.05	627.24	39.20

The small range of the evaporation from water in the tables is suggestive. It seems to approximate to a constant in each month. Of the tables of evaporation from earth, that at Whitehaven seems to be the better adapted to our climate. It is more valuable for the dry months than for winter.

The following is Risler's table of daily consumption of water for different crops, quoted in an article on irrigation by W. Tweeddale, C.E. (Kansas State Board of Agriculture Report, December 31st, 1889):

	Inches.	
Lucern grass	from 0.134	to 0.267
Meadow grass	" 0.122	" 0.287
Oats	" 0.140	" 0.193
Indian corn	" 0.110	" 1.570
Clover	" 0.140	" ....
Vineyard	" 0.035	" 0.031
Wheat	" 0.106	" 0.110
Rye	" 0.091	" ....
Potatoes	" 0.038	" 0.055
Oak trees	" 0.038	" 0.030
Fir trees	" 0.020	" 0.043

From these and other observations, Mr. Tweeddale concludes that from seed-time to harvest cereals will take up fifteen inches of water and grasses thirty-seven inches. These conclusions agree with practice in irrigation, and show plainly that the demands of plant growth cannot be ignored in tracing the disappearance of rain. The figures also explain the low summer flow of streams flowing from a highly-cultivated water-shed. They do not necessarily explain the effect of forests in regulating flow, since many water-sheds, although cleared of trees, are not put under cultivation but still show some change in flow. The action of forests is probably largely to retard surface-flow by means of irregular surfaces, caused by roots, fallen timber, absorbent mosses and leaf accumulation, thus holding the water until it can be taken into the ground. This is not mere theory; it is based on observations made during many days spent in the forest, and is believed to almost if not fully account for the better-sustained flow of forest streams and their lighter flood-flows.

Evidently, if all of our water-shed should be covered with grain and heavy grasses, there would be very little water left for the sustenance of stream-flow during the summer. Fortunately, a much smaller proportion is so covered than is usually supposed, even in agricultural sections. Somerset county is a highly-cultivated section of the red sandstone plain. I have made an estimate of the proportion of the total area given to various crops, based on census figures, and the proportion of wooded area has been measured. Of the total area, 13 per cent. is wooded in large tracts, and 7 per cent. has been added for scattering timber, the remainder being devoted to general farming:

TABLE No. 18.

Percentage of Areas Devoted to Various Crops in Somerset County, with Quantity of Water Required for Each.

CROP.	Per cent. of whole area.	WATER REQUIRED IN ONE GROWING-MONTH. In inches on crop area.	In inches on whole area.
Forest (oak and chestnut)	20	1.2	0.24
Wheat, rye, oats, &c	20	3.5	0.70
Indian corn	11	4.5	0.49
Potatoes and other root crops	5	1.2	0.06
Long grasses	17	6.0	1.02
Short grasses	15	5.0	0.75
Orchards, &c	5	3.0	0.15
Fallow lands and miscellaneous	7	4.0	0.28
Total	100	....	3.69

This gives a fair idea of the allowance which must be made for vegetation, although it is only a rough approximation. To this must be added something for extra evaporation from crop areas. This demand for 3.7 inches of water per month may be considered practically a constant one for the growing-months. It is, to a large degree, independent of the rainfall, and, in fact, a large part of the evaporation is also independent of rainfall.

Somerset county has been selected as a type of the larger part of our red sandstone plain, viz., that part lying southwest of the glacial moraine which passes through Morristown, Plainfield and Perth Amboy.

As a type of our Highland and Kittatinny valley region, Sussex county may be taken in the same way.

TABLE No. 19.

Percentage of Area Devoted to Various Crops in Sussex County, and Quantity of Water Required for Each.

CROP.	Per cent. of whole area.	WATER REQUIRED IN ONE GROWING-MONTH. In inches on crop area.	WATER REQUIRED IN ONE GROWING-MONTH. In inches on whole area.
Forest (oak and chestnut)	50	1.2	0.60
Water	2	5.0	0.10
Indian corn	5	4.5	0.22
Other cereals	9	3.5	0.32
Long grasses	3	6.0	0.18
Short grasses	24	5.0	1.20
Potatoes and other root crops	1	1.2	0.01
Fallow land	6	4.0	0.24
Total	100	....	2.87

The southern New Jersey agricultural counties will not differ very materially from Somerset county, while the piny region will only call for about one inch of water per month for plant growth. The evaporation there is large, however; much greater than in northern New Jersey, as we shall see when the study of the streams is taken up.

It would be difficult to determine just how much evaporation will take place in addition to the water demanded by plant growth. It is hardly probable that it is nearly so large as the evaporation from bare ground, and, for the heavier absorbents and closer-growing crops, such as long grasses and clover, there is probably no additional evaporation. The only practical way to fix the evaporation from different types of topography and country, under various stages of cultivation, is by means of a series of accurate gaugings of typical streams and synchronous measurements of rainfall. The above figures are not here intended to be given as actual measurements of the evaporation, and in no case do they apply to the actual conditions obtaining in practice. They are of value only as indicative of what may be expected and of the distribution of evaporation by months. For actual values we prefer to look to stream gaugings and learn what we can from these. If we take series of monthly rainfall and monthly stream-flow, such as we have given elsewhere in full, and carefully analyze them, we can determine what the evaporation will be for a given period. It would at first sight appear that it will be simply the difference between the rainfall and the stream-flow, but this error we must carefully guard against. It neglects entirely the water which may have been stored in or drawn from the earth.

GROUND-STORAGE.

The method of estimating the yield of streams to be a certain percentage of the rainfall also entirely neglects the effect of ground-storage. Much confusion as to the relative yield of streams and many failures to correctly interpret observed phenomena have resulted. Let us begin with the year and observe what the real sequence of events is.

At the close of the winter and spring rains, the ground is saturated with water to a great depth. A large amount of water is held in storage, and all of that which lies above the level of the bed of a stream, within the boundaries of the water-shed, becomes available either to feed the stream at that point or else to satisfy the demands of plants and evaporation. This great reservoir will feed a certain amount of water to the stream irrespective of the rainfall. If the rainfall is sufficient to supply the evaporation and plant growth, the flow from ground-water will remain constant, because the head which forces it through the rocks and gravels is constant. When the rain is insufficient, the head will be drawn down and the flow will decrease at a certain fixed rate. The draught upon ground-storage in this vicinity usually sets in between May 1st and June 1st, not often before the middle of May and rarely later than June 1st. Once the draught is fairly established and the water drawn down, unless the rainfall is greater than it usually is from June to August, it is all absorbed by the dried earth and does not reach down far enough to increase the head and consequent flow of ground-water. What may be called the under-run of a stream—the part which depends upon ground-storage—may be easily determined by inspection of a continuous diagram of flow. In inspecting such diagrams as those of the rivers of New Jersey accompanying this report, it may be seen that rainfalls which, if occurring in May, or in the autumn after the ground-water has been replenished, would cause violent floods, have no effect at all upon the stream-flow when they occur during the dry months. This difference in effect cannot be ascribed to direct evaporation, for in the case of concentrated rainfall, evaporation has little time to act. It is due to the drawing down of ground-water, which leaves a great capacity for absorption of rain by the earth.

In the analysis of recorded stream-flow following, it will be found that in extreme cases this stored ground-water will be drawn upon by stream-flow and evaporation to the extent of the equivalent of nine inches of rain. In some cases, it will yield to the streams alone a quantity of water equal to five inches of rainfall. A depletion of six inches by the end of August is not uncommon. This depletion must be made good before the fall rains become available to increase the stream-flow. Consequently, we frequently find the autumn stream-flow to be very much less than the difference between rainfall and evaporation.

Let us now observe what the effect of this ground-storage is upon the stream-flow. Take a usual case of a stream whose normal yield is 20 inches for 40 inches rainfall annually, and whose ground-storage will yield five inches to the stream. If we begin the year with full ground-water and end it with depleted ground-water, the yield will be 25 inches for 40 inches rainfall. If we begin with depleted ground-water, on the contrary, and end with full, we shall have but 15 inches yield for 40 inches rainfall. In the first case, we have a yield of 62.5 per cent., and in the second, but 37.5 per cent. of the rainfall. This stored ground-water will cause streams to continue to flow for weeks and months, even though rain entirely ceases to fall. Popularly, this is known as spring-water. It often issues in the form of well-sustained, visible springs, but a larger amount finds its way out unobserved all along the course of the stream. Portions of the surface which are permanently below the level of the surrounding ground-water are continually saturated, and are known as swamps or marshes. Wells sunk below its permanent level yield continuous supplies of water, popularly supposed to come from underground streams or "veins."

The actual distance below the surface of the ground to which this reserve supply of water is drawn during droughts is not everywhere the same, nor will all portions of a water-shed deliver equal amounts of water from the ground. A coarse gravel will contain more water to each foot of depth and will yield that water much more freely than compact earth or rock. When it is said that a water-shed will yield so many inches of water from ground-storage the average yield is intended. The accompanying sketch shows, generally, the manner in which a valley will yield up its ground-water during a protracted drought when the material is varied, and the phenomena which result therefrom and with which all are familiar.

The capacity for ground-storage varies widely on different water-sheds. On steep, rocky surfaces the rain largely runs off. The rock, it is true, holds a large amount of water, but it is held tenaciously, and discharged at a low rate. This fact is partially compensated for by the greater differences of level on such a water-shed, which cause greater heads to force out the water. A rocky water-shed, as level as the sandy basins of southern New Jersey, which discharge large volumes of ground-water, would probably yield a very trifling amount. Fanning gives the following data as to porosity of soils:

> "Gravel, consisting of small water-worn stones or pebbles, intermixed with grains of sand, has ordinarily 20 to 25 per cent. of voids; marl, consisting of limestone grains, clays and silicious sands, has from 10 to 20 per cent. of voids; pure clays have innumerable interstices, not easily measured, but capable of absorbing, after thorough drying, from 8 to 15 per cent. of an equal volume of water.
>
> "Water flows with some degree of freedom through sandstones, limestones and chalks, according to their textures, and they are capable of absorbing from 10 to 20 per cent. of their equal volumes of water.
>
> "The primary and secondary formations, according to geological classification, as for instance granites, serpentines, trappeans, gneisses, mica slates and argillaceous schists, are classed as impervious rocks, as are usually the several strata of pure clays that have been subjected to great superincumbent weight.
>
> "The crevices in the impervious rocks, resulting from rupture, may, however, gather and lead away, as natural drains, large volumes of the water of percolation."

It must be remembered, however, that nearly all water-sheds on rock formation have a covering of disintegrated rock and drift gravels and sands, which furnishes a large part of the ground-storage. A rock valley filled with drift sands and gravels, is admirably adapted to supply large quantities of ground-water.

From the above percentages, we find that a depletion of 9 inches of ground-water will draw down the water-table an average distance of from 35 to 45 inches in gravels, from 45 to 90 inches in marls, about 90 inches in clays, and from 45 to 90 inches in sandstones, limestones and chalks.

In this connection, it is worth while to remember that many plants project their roots to great depths in the earth. Common clover roots have been followed to a depth of four feet. It follows that vegetation, which must be supplied with water, will draw its supply from very considerable depths when no rainfall is available. As we shall see from our gaugings, the demands of evaporation and of plant-life are inexorable. During the growing-months of May, June and July, these demands are usually equal to the rainfall, and often in excess of it. Stream-flow is, consequently, entirely dependent upon the ground-water, which is also frequently further drawn upon by evaporation and plant-absorption. No scientific treatment of the yield of streams can neglect this important equalizing reservoir of ground-water.

SURFACE-STORAGE.

Another agent which tends to equalize flow to some extent, by carrying over some of the water of the wet season to the early dry months, thereby shortening the periods of very small flow, is surface-storage. Water is held in natural lakes and swamps and fed out gradually to the stream. Some of the natural lakes in northern New Jersey vary two feet in height of surface. The Paulinskill has about three square miles area of such lakes on 175 square miles of water-shed, and a storage of two feet would add to the stream-flow the equivalent of about one-half an inch of rainfall on the water-shed. Artificial storage is much more efficient, as a greater depth of water can be controlled and the discharge regulated to meet the demand. Natural storage is an important factor in the flow of some streams, such as those of our northern counties, however, and must be taken into account.

SURFACE OR FLOOD-FLOWS.

We have seen that a portion of our rain finds its way over the surface to the stream. How much, depends on the condition of the ground-water and the steepness of the slopes. On the Sudbury it is observed that any rainfall exceeding four inches per month is accompanied by surface-flows. There is some limit to the rapidity with

FRANKLIN LAKE, RAMAPO WATER-SHED.

which water can be absorbed by the earth, even when dry, and, although the ground-water is low, sometimes rain falls in such enormous volume that disastrous floods are caused.

In the report on Climatology of New Jersey (1888) it is stated that single storms "rarely exceed four inches in depth, and three inches is a heavy rain. In the Newark record the number of rains over three inches in thirty-seven years and eight months was thirty-six. Eight of them occurred in July; eight in August; five in October; three in November; two each in December and May, and one in each of the other months."

The late Ashbel Welch stated,* during a discussion on the flow of streams, that in August, 1843, "twelve inches of rain fell in about as many hours in one night" near Bound Brook, but this extremely heavy rainfall was confined to a very narrow district. He also says that "the most destructive rainstorms I have seen have been in August, and next to that, July."

The following severe storms are mentioned in the Climatology of New Jersey:

Paterson, March 19th and 20th, 1881, 5.44 inches in 11 hours; Parsippany, March, 1875, 7 inches in a single storm.

In the month of August, 1848, 22.48 inches of rain fell at Newark, a fall without an equal in the records of the vicinity.

In the month of September, 1882, great floods occurred all over the State. They were caused by a very heavy storm which came after three months of deficient rainfall. By the method employed in analyzing records of stream-flow, I find that by September 19th the deficiency of rain amounted to 7 inches on the Raritan water-shed. From the 20th to the 24th the records at New Brunswick show a fall of 11.84 inches of rain; those on the Croton water-shed showing about the same amount. It will be seen that there was a surplus of at least 4.5 inches after replenishing ground-water. As will be seen later, I have estimated that from the 22d to the 25th, during 64 hours, a total of 3.3 inches on the water-shed flowed over the dam above New Brunswick. The total flood-flow of the Passaic from this storm was practically the same, but it took eight days to deliver it, instead of 64 hours, owing to peculiarities which we shall discuss later. On the Sudbury, a smaller water-shed, from 5 to 10 per cent.

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* Transactions of the American Society of Civil Engineers, July, 1881.

of the total monthly rain has to be allowed when such rain exceeds 4 inches.

A striking example of the effect of the manner in which the rain falls, whether highly concentrated or evenly distributed through the months and year, is shown in the years 1889 and 1890. On the Raritan, in 1889, there occurred six floods high enough to destroy the fencing on the meadows along the stream. In 1890 there was but one flood over the river banks, and that a very light one. Our records of flow on the Passaic show five floods of from 6,300 to 10,900 cubic feet per second in 1889; in 1890 the discharge did not once reach 6,000 cubic feet per second, and 5,000 was exceeded only once. Both were years of heavy rainfall, 1889 having 68 inches against 51 inches in 1890. The distribution of rainfall in the latter year was phenomenally even.

A COLLECTION OF LONG-SERIES STREAM-GAUGINGS.

We must next seek to determine the relations which exist between rainfall, stream-flow and evaporation. In these studies we shall use the best existing data of measured stream-flow for streams near our own State, and where the climatic and geological conditions are somewhat similar to our own. It is the nature of the country drained by a stream which determines its peculiarities of flow. It is the amount of rainfall and of evaporation, the latter to a considerable extent dependent upon climate, which determines the ultimate yield of streams. Consequently it has not been thought wise to make use of records for remote water-sheds, even where they are available. It will greatly simplify these studies if we state the results of gaugings in inches of rainfall, thereby eliminating the differences due to size of water-shed. When we have reached conclusions, it will be easy to convert our results into ordinary liquid measures.

These gaugings are in the main reliable. Many startling apparent discrepancies in rainfall and flow are explained and verified by close analysis, so that we would warn our readers not to too hastily reject what may seem inexplicable, yet there are a few errors discoverable on close examination, and these we have guarded against in drawing our conclusions. It is not an easy matter to secure continuous accurate measurements of stream-flow, and still more difficult to obtain values of rainfall correctly representing the entire water-shed under consideration.

We base our conclusions as to relation between rainfall, evaporation and stream yield upon these long-series gaugings. The shorter series which we have obtained for our New Jersey streams will prove valuable for comparison with these, but are too short to depend upon without such comparison. No series which does not embrace a period as long as our rainfall cycle of 60 years can be considered entirely satisfactory, but fortunately some of these embrace years of extremely light and extremely heavy rainfall, and are in this respect all that can reasonably be asked for.

Sudbury River Gaugings.

The Sudbury river is at the extreme eastern end of Massachusetts, about fifteen miles west of Boston, and is one of the sources of water-supply for that city. In the Transactions of the American Society of Civil Engineers for July, 1881, we have given the results of gaugings by Mr. Alphonse Fteley, extending from January 1st, 1875, to February 29th, 1880, in a continuous series.

The figures in Table No. 20 are taken from Mr. Frederic P. Stearns' paper in the Twenty-second Annual Report of the State Board of Health of Massachusetts, and include the later records of the Boston water works. Mr. Fteley says of this water-shed:

> "The river, above the point where its waters are diverted, is formed by two principal affluents; the larger, draining about two-thirds of the gathering-grounds, rises in a hilly district and flows afterwards through an open valley with extensive swampy areas; the other flows through a hilly district, and although draining a territory only one-half as extensive, it has sometimes, after heavy rains, a volume as great as the larger stream. The whole water-shed controlled by the works covers seventy-eight square miles; a portion of it (from one-sixth to one-eighth) is covered with woods; the remainder, with the exception of areas occupied by several villages, has a general agricultural character."

The latitude of the Sudbury is about the same as that of Hudson, N. Y., and consequently still more northerly than the Croton.

From Mr. Stearns' report, we find that until 1878 the reservoir water-surface included in the drainage area was 1.02 per cent.; thence until 1886, 2.31 per cent., and afterwards 2.92 per cent. of the whole. He says:

"The flow of water past the lowest dam has been greatly modified by the use of the artificial reservoirs, but this does not appear in the records, because the amount flowing past the dam is corrected * * * to eliminate the effect of reservoirs and to present in the records the natural flow of the stream, modified only by such storage as is furnished by ordinary mill ponds and by White Hall pond. It cannot, however, be said that the effect of the reservoirs is wholly eliminated, because the evaporation from the increased water-surfaces is not taken into account, and the dry-weather flows recorded are consequently less than they would be if these reservoirs did not exist.

"The water-shed of the Sudbury river contains many hills with steep slopes, some of which are used for pasturage, and others are covered with a small growth of wood. The valleys, as a rule, are not steep, and there are extensive areas of swampy land, generally covered with a growth of brush and trees. The hills are, for the most part, of rather impervious, clayey material, containing boulders, while the flat land is sandy and in some cases gravelly."

With proper corrections and allowances, the Sudbury river represents conditions not unlike some of our Kittatinny valley and Highland streams, and being of about the same size as many of them, these records will be valuable to us in our studies.

TABLE No. 20.

Rainfall and Stream-flow on Sudbury River.

Area of water-shed, 78 square miles. Inches on the water-shed.

MONTH.	1875.		1875-6.	
	Rainfall.	Flow.	Rainfall.	Flow.
December	....	....	0.94	1.04
January	2.42	0.18	1.83	1.15
February	3.15	2.41	4.21	2.28
March	3.74	2.86	7.43	7.91
April	3.23	5.26	4.20	5.68
May	3.56	2.12	2.76	2.03
June	6.24	1.50	2.04	0.38
July	3.57	0.57	9.13	0.33
August	5.53	0.71	1.72	0.72
September	3.43	0.36	4.61	0.32
October	4.85	1.15	2.24	0.42
November	4.83	2.25	5.76	1.88
	44.55	19.37	46.87	24.14

Rainfall and Stream-flow on Sudbury River—Continued.

MONTH.	1876-7.		1877-8.	
	Rainfall.	Flow.	Rainfall.	Flow.
December	3.62	0.81	0.87	2.30
January	3.22	1.17	5.63	3.23
February	0.74	1.53	5.97	3.97
March	8.36	8.59	4.69	6.26
April	3.44	4.13	5.79	2.81
May	3.70	2.48	0.96	2.49
June	2.43	1.03	3.88	0.87
July	2.95	0.36	2.97	0.23
August	3.68	0.22	6.94	0.85
September	0.32	0.10	1.29	0.28
October	8.52	1.13	6.42	0.92
November	5.80	2.45	7.02	2.92
	46.78	24.00	52.43	27.13

	1878-9.		1879-80.	
December	6.37	5.67	4.34	0.83
January	2.48	1.25	3.57	2.00
February	3.56	2.76	3.98	2.98
March	5.14	4.16	3.32	2.45
April	4.72	5.38	3.11	2.02
May	1.58	1.99	1.84	0.92
June	3.79	0.71	2.14	0.30
July	3.93	0.28	6.27	0.32
August	6.51	0.71	4.01	0.21
September	1.88	0.24	1.60	0.14
October	0.81	0.13	3.74	0.18
November	2.68	0.36	1.79	0.35
	43.45	23.64	39.71	12.70

Rainfall and Stream-flow on Sudbury River—Continued.

MONTH.	1880-1.		1881-2.	
	Rainfall.	Flow.	Rainfall.	Flow.
December	2.83	0.31	3.96	1.38
January	5.56	0.74	5.95	2.21
February	4.65	2.49	4.55	3.87
March	5.73	7.14	2.65	5.06
April	2.00	2.67	1.82	1.50
May	3.51	1.72	5.07	2.30
June	5.40	2.31	1.66	0.91
July	2.35	0.49	1.77	0.15
August	1.36	0.26	1.67	0.10
September	2 62	0.34	8.74	0.53
October	2.96	0.33	2.07	0.53
November	4.09	0.68	1.15	0.36
	43.06	19.48	41.06	18.90

	1882-3.		1883-4.	
December	2.30	0.56	3.55	0.35
January	2.81	0.60	5.09	1.76
February	3.87	1.66	6.54	4.74
March	1.78	2.87	4.72	6.75
April	1.85	2.33	4.41	4.93
May	4.19	1.67	3.47	1.84
June	2.40	0.52	3.45	0.72
July	2.68	0.21	3.65	0.40
August	0.74	0.14	4.65	0.46
September	1.52	0.16	0.86	0.08
October	5.60	0.33	2.48	0.15
November	1.81	0.35	2.65	0.30
	31.55	11.40	45.52	22.48

Rainfall and Stream-flow on Sudbury River—Continued.

MONTH.	1884–5.		1885–6.	
	Rainfall.	Flow.	Rainfall.	Flow.
December	5.17	1.65	2.72	2.09
January	4.71	2.20	6.37	2.61
February	3.87	2.18	6.28	7.73
March	1.07	2.81	3.61	3.67
April	3.61	3.13	2.23	3.36
May	3.49	2.38	3.00	1.29
June	2.87	0.74	1.47	0.35
July	1.43	0.11	3.27	0.21
August	7.19	0.43	4.10	0.17
September	1.43	0.21	2.91	0.20
October	5.10	0.60	3.24	0.26
November	6.10	2.03	4.65	1.16
	46.04	18.47	43.85	23.10

	1886–7.		1887–8.	
December	4.98	1.82	3.88	1.15
January	5.20	4.62	4.15	1.88
February	4.78	4.56	3.69	3.26
March	4.90	5.12	6.02	5.76
April	4.27	4.52	2.43	4.57
May	1.17	1.80	4.83	2.91
June	2.65	0.71	2.54	0.73
July	3.76	0.20	1.41	0.21
August	5.28	0.38	6.22	0.68
September	1.32	0.19	8.59	1.99
October	2.84	0.34	4.99	3.57
November	2.67	0.64	7.23	4.76
	43.82	24.90	55.98	31.47

Rainfall and Stream-flow on Sudbury River—Continued.

MONTH.	1888-9.		1889-90.	
	Rainfall.	Flow.	Rainfall.	Flow.
December	5.40	5.43	3.14	4.00
January	5.37	4.96	2.53	2.24
February	1.66	1.93	3.51	2.46
March	2.37	2.39	7.74	6.50
April	3.41	2.43	2.65	3.24
May	2.95	1.57	5.21	2.44
June	2.80	1.13	2.03	0.98
July	8.94	1.13	2.46	0.19
August	4.18	2.55	3.87	0.24
September	4.61	1.42	6.00	0.79
October	4.26	2.19	10.51	4.05
November	6.29	3.35	1.20	2.10
	52.24	30.48	50.85	29.23

Connecticut River Gaugings.

On the Connecticut, at Hartford, gaugings have been made by the United States Army Engineer Corps, and the results given here we have compiled from their reports. The great difficulty we have found with this series has been to obtain adequate cotemporaneous rainfall records. Everything available has been collected, and the rainfall carefully compiled, and the results given are believed to be the best now obtainable, This river corresponds in a general way with the Delaware, and is the largest stream for which we have reliable records. If we keep in mind the fact that it lies on an average two degrees farther north than the Delaware above Trenton, and make proper allowances for this and other differences, it becomes useful in our studies of the latter river. The headwaters of the Connecticut are in the White mountain region, and throughout the water-shed is rugged. We estimate that about 47 per cent. of the whole area is improved land. The remainder is fallow or covered with timber in various stages of growth.

TABLE No. 21.

Rainfall and Stream-flow on Connecticut River.

Area of water-shed, 10,234 square miles. In inches on the water-shed.

MONTH.	1871.		1871-2.	
	Rainfall.	Flow.	Rainfall.	Flow.
December	....	....	3.02	1.44
January	....	....	1.60	1.23
February	2.45	1.87	2.25	0.79
March	4.04	5.65	2.18	0.94
April	3.21	2.79	1.28	5.51
May	3.60	3.40	4.62	3.46
June	3.30	1.00	5.52	2.68
July	3.49	0.70	5.75	1.13
August	5.89	0.81	8.53	2.52
September	1.68	0.85	3.85	2.25
October	3.57	1.02	3.24	1.76
November	2.68	1.66	3.85	2.65
	33.91	19.75	45.69	26.36

	1872-3.		1873-4.	
December	3.10	1.92	3.17	2.81
January	3.70	2.71	4.08	5.70
February	2.33	1.90	2.18	4.07
March	3.88	1.82	1.94	3.02
April	2.45	7.65	5.26	2.61
May	2.62	5.83	3.61	5.86
June	1.50	1.11	5.29	3.12
July	5.60	0.80	6.04	2.31
August	3.02	0.73	3.23	1.19
September	4.45	0.75	3.00	0.73
October	6.40	2.81	1.48	0.81
November	3.33	1.68	2.22	0.67
	42.38	29.71	41.50	32.90

Rainfall and Stream-flow on Connecticut River—Continued.

MONTH.	1874–5.		1875–6.	
	Rainfall.	Flow.	Rainfall.	Flow.
December	1.82	0.76	1.27	1.83
January	3.40	0.72	2.64	3.36
February	2.95	1.14	4.43	2.71
March	3.18	2.06	6.02	3.95
April	2.54	6.14	2.61	6.76
May	3.24	4.69	3.44	6.54
June	4.80	1.50	4.59	1.73
July	3.50	0.97	5.34	0.93
August	4.84	1.35	0.97	0.70
September	3.03	0.74	5.31	0.72
October	4.46	1.15	1.25	0.71
November	3.07	1.73	2.76	0.88
	40.83	22.95	40.63	30.82

	1876–7.		1877–8.	
December	3.88	0.72	1.44	1.95
January	2.54	0.74	3.20	1.26
February	0.62	0.78	2.56	2.06
March	5.16	3.92	2.23	3.67
April	2.35	4.64	7.52	5.21
May	1.26	1.91	2.64	3.59
June	4.92	0.88	4.79	1.51
July	6.01	1.07	3.29	0.87
August	3.32	0.97	4.23	1.12
September	1.38	0.76	2.34	0.84
October	6.18	1.34	2.34	0.80
November	5.14	3.19	4.11	1.81
	42.76	20.92	40.69	24.69

Croton River Gaugings.

The Croton river is well known as the source of supply for the city of New York. From careful measurements we find the area of water-shed above Croton dam to be 353.1 square miles. The country embraced in this area is hilly and the rock is mainly gneissic. It is overlaid with drift earths and gravel to some extent. The valleys are rather flat-bottomed, and the upper portions of the East Branch are bordered by narrow swamps. About 30 per cent. is covered with timber or brush, the remainder being tillable or pasture land. There are some forty natural lakes and mill-ponds, aggregating about 1.3 per cent. of the whole area. The artificial Croton lake at the outlet raised this to 1.5 per cent.

In 1873 Boyds Corner reservoir was completed, making the total water area 1.6 per cent., and in 1878 the Middle Branch reservoir came into use, raising the whole water area to 1.8 per cent. The correction for this storage has not been made in the first record for lack of data. In my analysis later I have corrected where it was necessary. Our record ends with 1881. Since that date several storage reservoirs have been added, and the stream has consequently become less valuable as a guide to natural flow.

The series of gaugings below I have compiled from data published by the Department of Public Works of New York City, in the Commissioner's report on the new aqueduct, in February, 1882. The flow over Croton dam is given from 1865 to 1881, but lacking the flow through the aqueduct, I have only been able to obtain the total flow from 1868, or for fourteen years. The method of gauging was crude, the height being measured once a day at Croton dam. Only a good approximation was desired, however, and it appears to have been obtained.

TABLE No. 22.

Rainfall and Flow of Croton Water-shed.

Area of water-shed, 353.1 square miles. In inches on the water-shed.

MONTH.	1868.		1869.	
	Rainfall.	Flow.	Rainfall.	Flow.
January	2.90	1.95	3.79	2.17
February	1.38	0.79	3.64	0.39
March	2.55	3.83	5.48	4.71
April	3.87	4.60	2.11	3.16
May	8.79	5.44	4.52	2.75
June	4.53	3.17	3.59	1.43
July	2.13	0.98	2.26	0.54
August	6.98	1.73	1.92	0.33
September	9.33	4.69	3.20	0.23
October	0.87	2.84	9.46	2.39
November	4.65	3.80	2.43	1.87
December	2.35	0.97	5.96	2.95
	50.33	34.80	48.36	22.87

	1870.		1871.	
January	4.51	3.76	3.80	0.52
February	6.40	3.64	3.81	1.61
March	3.80	3.24	4.27	3.36
April	5.45	4.00	3.01	1.90
May	2.30	1.69	3.45	2.90
June	2.06	0.70	5.73	1.24
July	3.43	0.46	5.07	0.69
August	5.10	0.43	5.24	0.68
September	2.85	0.32	1.44	0.55
October	4.73	0.40	6.18	1.60
November	2.51	0.56	4.35	3.60
December	1.49	0.59	2.59	2.10
	44.63	19.79	48.94	20.75

Rainfall and Flow of Croton Water-shed—Continued.

MONTH.	1872.		1873.	
	Rainfall.	Flow.	Rainfall.	Flow.
January	1.44	1.88	5.66	3.72
February	1.22	1.07	3.09	1.70
March	2.59	1.31	3.08	3.29
April	3.04	2.97	3.77	6.44
May	3.69	1.20	2.91	7.43
June	4.00	1.14	0.71	0.50
July	4.34	0.55	2.21	0.48
August	5.99	1.24	5.73	0.53
September	3.69	1.13	3.73	0.47
October	2.15	1.07	5.13	1.09
November	4.91	2.48	3.72	1.50
December	3.68	1.38	4.13	3.13
	40.74	17.42	43.87	30.28

	1874.		1875.	
January	6.96	3.89	2.74	0.57
February	2.78	2.58	3.47	2.90
March	1.57	2.88	4.99	2.63
April	6.31	3.33	3.04	4.83
May	1.99	2.90	1.08	1.68
June	3.57	0.88	3.02	0.54
July	5.98	0.85	3.10	0.54
August	2.75	0.69	10.33	4.41
September	3.56	0.51	2.11	0.82
October	2.40	0.70	3.61	0.53
November	2.72	0.59	4.61	1.96
December	1.78	0.85	1.56	1.73
	42.37	20.65	43.66	23.14

Rainfall and Flow of Croton Water-shed—Continued.

MONTH.	1876.		1877.	
	Rainfall.	Flow.	Rainfall.	Flow.
January	1.42	1.42	2.68	0.76
February	4.91	3.28	0.80	1.37
March	6.33	5.75	7.66	6.35
April	4.43	5.21	2.35	2.80
May	3.99	1.89	0.85	0.82
June	2.52	0.62	4.95	0.55
July	3.42	0.52	4.65	0.50
August	1.20	0.49	2.54	0.48
September	5.21	0.36	1.49	0.32
October	1.50	0.37	8.38	0.71
November	3.40	0.60	8.16	3.76
December	2.35	0.62	1.52	3.90
	40.68	21.13	46.03	22.32

	1878.		1879.	
January	4.49	2.46	2.52	1.37
February	3.65	3.32	2.85	2.21
March	3.10	3.64	4.96	3.92
April	2.85	1.61	5.10	4.70
May	4.97	1.48	2.45	1.86
June	4.65	1.32	5.29	0.78
July	4.28	0.62	5.95	0.62
August	2.66	0.62	5.83	1.04
September	6.61	1.69	3.43	0.99
October	3.78	0.77	0.95	0.63
November	4.36	1.70	2.49	0.75
December	8.74	6.49	4.26	1.88
	54.14	25.72	46.08	20.75

Rainfall and Flow of Croton Water-shed—Continued.

MONTH.	1880.		1881.	
	Rainfall.	Flow.	Rainfall.	Flow.
January	4.00	2.62	4.19	0.65
February	2.92	2.75	5.28	2.95
March	4.51	2.89	6.14	5.42
April	3.99	1.96	1.67	1.69
May	1.17	0.85	3.74	1.26
June	1.28	0.49	5.27	1.46
July	5.65	0.50	2.45	0.53
August	3.60	0.50	1.71	0.50
September	2.69	0.48	0.75	0.49
October	3.25	0.50	3.65	0.50
November	2.97	0.49	4.50	0.50
December	2.49	0.51	6.37	1.49
	38.52	14.54	45.72	17.44

Passaic River Gaugings.

The next series of gaugings is for one of our own most important rivers. These gaugings are compiled partially from records furnished this Survey by private parties, and partially from our own observations. The gaugings are at points from Little Falls to Dundee, and have all been carefully reduced, compared and referred to Dundee dam. Every precaution has been taken to eliminate errors, and as it stands the record is a most valuable one for our purposes. We are particularly fortunate to have obtained the data which have here been utilized. The Passaic above Dundee is in all respects a fair average type of our northern New Jersey streams, although it has certain peculiarities which we shall point out when we take up the study of the stream in detail. For a full description of the water-shed we refer the reader to the Topographical Atlas.

TABLE No. 23.

Rainfall and Stream-flow, Passaic River.

Area of water-shed, 822 square miles. In inches on water-shed.

MONTH.	1877.		1877–8.	
	Rainfall.	Flow.	Rainfall.	Flow.
December	....	....	1.01	2.53
January	3.81	.92	5.35	2.67
February	1.48	2.30	3.82	3.75
March	6.30	6.02	3.35	3.84
April	3.00	3.06	1.50	1.43
May	.97	.98	4.59	1.77
June	4.37	.63	3.03	1.67
July	4.87	.44	5.00	.80
August	6.11	.60	5.99	1.62
September	1.98	.36	2.46	.52
October	7.25	2.98	3.17	.49
November	6.93	5.34	3.48	1.75
	47.07	23.63	42.75	22.84

	1878–9.		1879–80.	
December	5.69	6.83	5.04	2.42
January	2.87	.82	2.40	3.55
February	2.21	1.83	2.72	2.64
March	3.75	4.12	4.12	2.55
April	4.61	4.37	2.89	2.09
May	2.51	1.71	.61	1.04
June	4.17	.97	1.44	.32
July	5.10	.45	7.69	.42
August	8.18	1.60	4.87	*.50
September	2.77	.93	2.18	*.48
October	.29	.24	1.70	.22
November	2.00	.26	2.32	.74
	44.16	24.13	37.98	16.97

*Missing from record. These values from Croton series.

Rainfall and Stream-flow, Passaic River—Continued.

MONTH.	1880–1.		1881-2.	
	Rainfall.	Flow.	Rainfall	Flow.
December	2.70	.68	4.59	1.65
January	4.08	1.14	5.63	2.20
February	4.57	3.59	4.31	6.90
March	5.10	6.77	3.23	4.35
April	1.04	1.68	2.05	1.23
May	2.78	.89	6.45	3.04
June	5.42	1.89	3.43	1.90
July	1.85	.39	3.32	.94
August	.90	.27	2.43	.26
September	1.06	.26	10.74	3.86
October	3.08	.25	2.06	1.68
November	3.12	.57	1.59	.57
	35.70	18.38	49.83	28.58

	1882–3.		1883–4.	
December	1.88	1.14	3.36	.75
January	3.75	.91	5.16	2.83
February	4.24	3.03	4.54	6.21
March	2.03	3.16	4.75	5.01
April	3.91	2.94	2.43	2.68
May	2.92	1.67	2.92	1.85
June	4.93	.71	4.45	.64
July	2.96	1.04	5.21	1.33
August	2.13	.38	5.81	.88
September	4.13	.35	.61	.32
October	5.67	1.09	3.38	.59
November	1.35	1.30	3.39	.99
	39.90	17.72	46.01	24.08

Rainfall and Stream-flow, Passaic River—Continued.

MONTH.	1884–5.		1885–6.	
	Rainfall.	Flow.	Rainfall.	Flow.
December	5.52	3.36	3.20	3.25
January	4.18	4.15	4.83	3.54
February	4.82	2.24	4.61	5.68
March	1.27	1.96	3.68	2.64
April	1.53	3.50	3.41	5.10
May	2.55	1.68	6.10	3.38
June	1.20	.52	2.73	1.04
July	4.08	.42	3.81	.52
August	7.26	.78	2.55	.49
September	.66	.26	1.36	.31
October	4.95	.76	2.55	.33
November	5.53	2.73	4.92	.92
	43.55	22.36	43.75	27.20

	1886–7.		1887–8.	
December	3.57	1.15	5.72	2.32
January	4.45	2.84	5.77	4.61
February	5.10	4.84	4.41	3.90
March	2.87	3.63	6.68	4.97
April	2.53	2.66	3.97	6.13
May	1.93	1.10	6.09	.69
June	6.65	2.04	2.80	.38
July	8.82	2.29	1.98	.36
August	4.27	1.35	7.60	1.00
September	2.01	.38	8.06	4.19
October	2.14	.66	4.53	2.65
November	1.75	.59	4.09	3.00
	46.09	23.53	61.70	34.20

Rainfall and Stream-flow, Passaic River—Continued.

MONTH.	1888-9.		1889-90.	
	Rainfall.	Flow.	Rainfall.	Flow.
December	4.33	4.51	2.14	4.40
January	6.04	5.75	2.69	2.01
February	2.41	2.28	4.59	3.24
March	3.22	2.19	6.03	3.30
April	6.34	3.41	2.58	2.99
May	2.85	2.85	4.39	2.74
June	3.43	1.65	4.55	1.78
July	14.49	2.31	6.14	1.47
August	4.49	4.14	4.96	1.04
September	10.06	3.90	3.73	1.52
October	3.06	2.15	5.20	2.49
November	10.16	6.29	.75	1.37
	70.88	42.23	47.75	28.35

	1890-1.		1891-2.	
December	4.17	1.98	4.73	2.04
January	7.52	5.92	5.38	5.34
February	4.55	5.41	1.35	1.55
March	4.24	5.30	4.19	2.66
April	2.30	2.49	1.69	1.43
May	2.80	.94	4.92	1.42
June	1.86	.44	4.68	1.20
July	5.16	.31	3.27	.52
August	5.72	.83	4.39	.53
September	2.25	.64	2.17	.40
October	2.50	.31	.72	.25
November	2.96	.63	6.84	1.38
	46.03	25.20	44.33	18.72

Rainfall and Stream-flow, Passaic River—Continued.

MONTH.	1892-3.		1893-4.	
	Rainfall.	Flow.	Rainfall.	Flow.
December	1.47	1.18	3.85	1.74
January	3.87	3.86	....	....
February	6.35	5.65	....	....
March	3.43	6.95	....	....
April	4.59	4.88	....	....
May	5.15	4.88	....	....
June	3.60	2.32	....	....
July	2.25	0.71	....	....
August	7.26	1.05	....	....
September	2.92	0.58	....	....
October	4.59	1.25	....	....
November	3.65	1.30	....	....
	49.13	34.61	....	....

Tohickon Creek Gaugings.

This series is compiled from the records printed in the annual reports of the Chief Engineer of the Philadelphia Water Department for the years covered. The Tohickon is a branch of the Delaware, which it joins at Point Pleasant, about eight miles above Lambertville. The water-shed is similar in its topography to the southern portion of Hunterdon county, in this State. The country rock is Triassic red shale. About 28 per cent. is timber and waste land, and 72 per cent. cultivated. Elevations range from 400 to 1,000 feet above tide, and the upper half is a rather level plateau with a general elevation of 500 feet.

TABLE No. 24.

Rainfall and Stream-flow, Tohickon Creek, Pa.

Area of water-shed, 102.2 square miles. In inches on the water-shed.

	1885.	
	Rainfall.	Flow.
October	4.80	.34
November	4.67	2.57

MONTH.	1885-6.		1886-7.	
	Rainfall.	Flow.	Rainfall.	Flow.
December	3.06	1.78	3.83	2.38
January	4.15	4.36	4.24	5.04
February	6.01	9.19	5.47	5.25
March	4.76	4.28	3.07	3.83
April	3.42	4.76	2.41	1.01
May	7.14	3.43	2.59	.93
June	4.53	1.40	5.77	1.21
July	5.48	.77	8.13	1.63
August	1.09	.10	5.29	1.96
September	1.30	.03	3.36	.40
October	2.59	.05	1.93	.25
November	5.16	1.96	1.42	.26
Year	48.69	32.11	47.51	24.15

	1887-8.		1888-9.	
December	6.53	3.20	4.35	3.48
January	5.31	6.38	4.43	4.38
February	4.34	6.72	2.37	1.52
March	5.23	6.27	3.67	3.86
April	4.08	4.28	4.90	2.88
May	3.03	.52	5.41	1.70
June	1.69	.15	6.94	2.29
July	3.20	.06	12.33	6.41
August	8.07	1.77	4.63	3.75
September	8.32	5.49	7.92	3.40
October	4.06	1.54	4.57	2.33
November	3.66	3.11	8.86	7.97
	57.52	39.49	70.38	43.97

Rainfall and Stream-flow, Tohickon Creek, Pa.—Continued.

MONTH.	1889-90.		1890-1.	
	Rainfall.	Flow.	Rainfall.	Flow.
December	1.99	1.92	2.75	1.51
January	2.82	2.06	6.15	6.15
February	4.72	3.78	4.58	5.68
March	6.77	6.37	4.79	5.03
April	2.48	1.79	1.97	1.58
May	6.30	3.09	2.83	.28
June	3.93	.75	3.38	.17
July	5.81	.87	7.49	.90
August	5.75	.92	8.90	3.92
September	2.99	1.22	1.37	.94
October	6.20	3.54	3.81	.46
November	1.07	.69	1.98	.63
	50.83	27.00	50.00	27.25

	1891-2.		1892-3.	
December	5.09	4.28	1.84	1.68
January	5.49	6.53		
February	1.23	1.19		
March	4.13	4.87		
April	1.95	.84		
May	5.55	2.05		
June	3.19	.70		
July	4.27	.51		
August	3.76	.30		
September	2.91	.19		
October	.52	.10		
November	7.15	3.19		
	45.24	24.75		

Neshaminy Creek Gaugings.

This record is also from the above-quoted reports of the Chief Engineer of the Philadelphia Water Department.

Neshaminy creek is a tributary of the Delaware, and the portion of its water-shed here treated of lies in the vicinity of Doylestown, Pa. The surface is rolling, ranging from 250 to 700 feet in elevation. Only 7 per cent. is wooded or fallow, 93 per cent. being improved. In its general character this water-shed resembles those of our red sandstone district southwest of the moraine line at Plainfield and Perth Amboy.

TABLE No. 25.

Flow of the Neshaminy Below Forks, Pa.

Area of water-shed, 139.3 square miles. In inches on water-shed.

	1885.	
	Rainfall.	Flow.
October	5.56	.17
November	4.50	1.53

MONTH.	1885–6.		1886–7.	
	Rainfall.	Flow.	Rainfall.	Flow.
December	2.88	1.73	3.30	2.34
January	5.11	5.21	4.64	4.22
February	6.18	6.55	5.05	3.94
March	3.71	2.30	3.57	3.25
April	2.93	3.57	3.18	1.46
May	5.79	2.09	2.15	.71
June	5.67	.91	7.27	1.67
July	5.40	.81	8.15	1.96
August	1.60	.14	3.84	.81
September	.91	.05	4.06	.41
October	2.77	.06	1.90	.36
November	3.92	.55	1.63	.23
Year	46.87	23.97	48.74	21.36

Flow of the Neshaminy Below Forks, Pa.—Continued.

MONTH.	1887–8.		1888–9.	
	Rainfall.	Flow.	Rainfall.	Flow.
December	6.13	2.89	3.72	3.16
January	4.47	4.60	3.61	2.92
February	3.98	5.49	1.90	.90
March	5.15	4.89	3.37	2.90
April	3.88	2.79	4.83	2.07
May	2.87	.52	4.90	1.49
June	2.34	.22	5.25	1.16
July	3.71	.15	12.42	5.47
August	5.78	.64	4.75	3.37
September	6.93	2.63	8.56	3.51
October	3.76	1.05	5.09	2.55
November	3.49	2.34	8.53	6.31
Year	52.49	28.21	66.93	35.81

	1889–90.		1890–1.	
December	1.88	1.88	2.86	1.37
January	2.08	1.60	6.28	5.78
February	4.28	3.00	4.61	4.47
March	5.36	5.09	4.91	4.32
April	2.46	1.77	1.90	1.48
May	5.20	1.51	2.92	.32
June	4.51	.99	3.46	.24
July	4.47	.63	5.71	.34
August	5.30	.53	6.73	1.95
September	3.00	.39	2.54	1.27
October	6.18	2.16	3.66	.55
November	1.06	.78	1.88	.56
Year	45.78	20.33	47.46	22.65

Flow of the Neshaminy Below Forks, Pa.—Continued.

MONTH.	1891–2.		1892–3.	
	Rainfall.	Flow.	Rainfall.	Flow.
December	4.19	3.02	1.69	1.15
January	5.09	5 14	....	....
February	1.06	.97	....	....
March	4.13	3.56	....	....
April	2.24	1.03	....	....
May	5.83	1.28	....	....
June	3.38	.57	....	....
July	4.83	.53	....	....
August	3.37	.20	....	....
September	2.59	.10	....	....
October	.40	.04	....	....
November	7.14	1.76	....	....
Year	44.25	18.20	....	....

Perkiomen Creek Gaugings.

These are also from the above-quoted reports of the Chief Engineer of the Philadelphia Water Department. This water-shed lies between Quakertown and Pottstown, Pa., and adjoining the two previous water-sheds on its northeast border. Elevations range from 200 to about 1,100 feet. The northwestern headwaters are in a quite hilly country. The remainder is rolling and similar to the watershed of the Neshaminy. Woods cover 25 per cent. of the watershed. The remainder is under cultivation.

TABLE No. 26.

Rainfall and Stream-flow, Perkiomen Creek, Pa.

Area of water-shed, 152.0 square miles. In inches on water-shed.

	1885.	
	Rainfall.	Flow.
October	4.74	.43
November	3.88	1.79

MONTH.	1885–6.		1886–7.	
	Rainfall.	Flow.	Rainfall.	Flow.
December	3.18	2.45	3.76	1.43
January	4.21	3.03	4.55	4.00
February	5.08	5.64	5.64	4.23
March	3.96	2.58	3.00	3.03
April	3.00	3.42	2.84	1.25
May	6.59	2.64	1.85	.72
June	5.26	1.89	5.87	.76
July	5.06	1.11	8.63	2.07
August	1.44	.35	2.76	1.43
September	1.37	.23	3.64	.62
October	2.36	.26	1.44	.43
November	5.28	1.53	1.61	.40
	46.79	25.13	45.59	20.37

	1887–8.		1888–9.	
December	6.65	2.13	4.37	2.89
January	5.01	3.66	3.86	3.27
February	4.08	4.41	1.99	1.47
March	5.15	5.10	3.17	3.01
April	3.43	3.45	5.05	2.07
May	3.16	.92	4.55	1.58
June	1.62	.39	7.16	2.65
July	2.77	.25	12.23	4.89
August	8.02	1.53	4.00	2.48
September	7.36	3.68	7.00	2.80
October	3.41	1.26	4.78	2.34
November	3.42	2.46	8.67	6.67
	54.08	29.24	66.83	36.12

Rainfall and Stream-flow, Perkiomen Creek, Pa.—Continued.

MONTH.	1889–90.		1890–1.	
	Rainfall.	Flow.	Rainfall.	Flow.
December	1.70	1.27	2.71	1.14
January	2.81	2.05	6.30	5.29
February	4.37	3.58	3.84	4.18
March	6.56	5.58	6.07	4.29
April	2.80	2.60	1.98	1.80
May	6.43	3.15	1.99	.66
June	2.40	.94	3.01	.36
July	5.20	1.09	7.73	.85
August	6.75	1.08	7.57	2.04
September	3.71	1.30	2.63	1.53
October	5.48	2.36	3.52	.56
November	1.12	.87	1.99	.60
	49.33	25.87	49.34	23.30

	1891–2.		1892–3.	
December	4.73	2.89	1.89	1.23
January	5.57	4.79	....	....
February	1.25	1.17	....	....
March	5.00	4.05	....	....
April	1.78	1.16	....	....
May	5.33	1.83	....	....
June	3.18	.89	....	....
July	5.19	.73	....	....
August	2.70	.76	....	....
September	2.21	.33	....	....
October	.46	.21	....	....
November	6.64	2.11	....	....
	44.04	20.92	....	....

Potomac River Gaugings.

The Potomac record we have taken from a paper by Cyrus C. Babb, in the Transactions of the American Society of Civil Engineers. The observations were made for the United States Geological Survey at Great Falls, Md. The following description is from Prof. Geo. F. Swain's report, in Volume 16, Tenth Census of the United States, "Water-Power:"

"The two branches which form the river rise in the Alleghenies, the north branch near the western corner of the State of Maryland, and the south branch in Virginia and West Virginia, near the sources of Cowpasture and Jackson's rivers (the headwaters of the James), whence it flows nearly north. These branches, with their affluents, and the tributaries of the main stream as far down as the Shenandoah, drain a series of narrow and generally fertile valleys lying between the parallel ranges which make up the system of the Alleghenies in this region. Their falls are, as a rule, not very large, their declivities uniform, and their beds gravel and sand. Their chief peculiarity lies in the fluctuations to which their flow is liable. The rain falling on the mountains is shed rapidly into the water-courses by the steep side slopes leading to the narrow valleys below, and there being few lowlands to overflow, and so to store the freshet-water, and no lakes whatever in the region, these streams, and with them the Potomac river, are subject to very sudden and heavy freshets, while in dry seasons their discharge becomes very small. * * * From the junction of its two branches, the Potomac cuts through the mountains nearly at right angles. Its valley in this part of its course is narrow, its fall at places quite rapid, the bed generally gravel, bowlders and sand, with rock at small depth and often at the surface, and the banks generally high and sometimes precipitous, with not many low grounds subject to overflow."

TABLE No. 27.

Rainfall and Stream-flow, Potomac River.

Area of water-shed, 11,043 square miles. In inches on the water-shed.

MONTH.	1885-6.		1886-7.	
	Rainfall.	Flow.	Rainfall.	Flow.
December	....	....	2.60	1.14
January	4.40	1.43	2.38	1.27
February	3.52	2.20	3.88	2.28
March	4.59	.58	2.86	2.84
April	3.81	4.46	3.56	1.42
May	8.61	2.52	3.51	2.62
June	6.34	.30	4.44	1.43
July	6.81	.55	5.04	.64
August	2.58	.63	2.17	.37
September	2.21	.34	3.58	.37
October	1.60	.35	1.21	.35
November	4.03	.80	1.17	.33
Year	48.50	14.16	36.40	15.06

	1887-8.		1888-9.	
December	3.23	.58	2.60	1.43
January	3.27	1.33	3.97	3.26
February	2.71	2.70	1.85	1.77
March	3.68	3.01	4.37	3.95
April	2.01	1.82	5.14	3.61
May	3.71	1.11	5.15	1.98
June	3.40	.88	9.55	4 65
July	3.65	1.94	4.18	1.00
August	4.78	.51	3.83	1.71
September	5.34	1.70	4.91	2 57
October	2.74	.74	3.70	3.08
November	3.09	1.66	5.95	6.58
Year	41.61	17.98	55.20	35.59

Rainfall and Stream-flow, Potomac River—Continued.

MONTH.	1889-90.		1890-1.	
	Rainfall.	Flow.	Rainfall.	Flow.
December	1.20	2.90	3.14	.88
January	1.44	1.01	3.79	4.25
February	3.98	3.68	4.15	7.54
March	4.16	5.09	6.09	6.23
April	3.11	2.56	3.23	7.22
May	6.86	5.26	2.80	.65
June	2.92	2.07	4.83	2.23
July	3.04	.67	6.61	1.22
August	5.49	.71	4.02	.74
September	4.15	.80	2.98	.61
October	5.59	2.46	1.09	.41
November	1.04	.94	1.98	.46
Year	42.98	28.15	44.71	32.44

	1891-2.	
	Rainfall.	Flow.
December	2.77	1.01

I have not deemed it necessary to add to this collection. It embraces, so far as I have learned, the best material obtainable for the eastern United States, and is sufficiently comprehensive for our purposes.

ANALYSIS OF GAUGINGS.

Our first step must be to trace the relationship between annual rainfall, stream-flow and evaporation. Throughout this analysis it will be impossible and useless to attempt to carry the reader through all the detail of the processes by which our results are reached, and we only aim to give so much of it as will enable him to follow in outline our method. First correcting the observed yearly rainfall and flow to allow for rain carried over to the following year, and for water drawn from ground-storage when we find such correction to be necessary, and then grouping the years in classes corresponding closely in the amount of rainfall, and taking the averages for each such group, we obtain the results shown in Table No. 28.

TABLE No. 28.

Yearly Rainfall, Flow and Evaporation from Gaugings.

SUDBURY WATER-SHED, MEAN LATITUDE, 42° 15′.

Rainfall.	Stream-flow.	Evaporation.
31.55	11.40	20.15
39.40	18.08	21.32
43.97	22.31	21.66
46.39	23.54	22.85
50.85	27.23	23.62
52.33	28.80	23.53
55.98	31.97	24.01

CONNECTICUT WATER-SHED, MEAN LATITUDE, 43° 30′.

Rainfall.	Stream-flow.	Evaporation.
43.84	27.33	16.51

CROTON WATER-SHED, MEAN LATITUDE, 41° 20′.

Rainfall.	Stream-flow.	Evaporation.
40.07	18.67	21.40
44.42	22.29	22.13
47.06	23.29	23.77
50.05	27.33	22.72

PASSAIC WATER-SHED, MEAN LATITUDE, 41° 00′.

Rainfall.	Stream-flow.	Evaporation.
38.52	17.55	20.97
43.49	23.11	20.38
46.30	24.11	22.19
61.70	36.90	24.80
70.88	45.23	25.65

TOHICKON WATER-SHED, MEAN LATITUDE, 40° 25′.

Rainfall.	Stream-flow.	Evaporation.
46.38	24.45	21.93
50.42	27.13	23.29
70.38	43.97	26.41

NESHAMINY AND PERKIOMEN WATER-SHEDS, MEAN LATITUDE, 40° 20′.

Rainfall.	Stream-flow.	Evaporation.
44.91	19.95	24.96
45.69	20.35	25.34
49.14	23.52	25.62
60.09	32.35	27.74

POTOMAC WATER-SHED, MEAN LATITUDE, 39° 50′.

Rainfall.	Stream-flow.	Evaporation.
45.43	20.70	24.73

The Connecticut gaugings are very unsatisfactory. I have merely given above an average for the year, embodying the entire series. When we come to separate them into six-month periods we shall see that most of the irregularity is in the winter flow. Consequently we shall postpone further consideration of the Connecticut. The Potomac series also is best treated by periods. Above I have taken the means for four years, rejecting two years for the present as questionable. There is a strong probability that either the rainfall or flow observations are in both cases somewhat faulty. Let us first study the Sudbury, Croton and Passaic gaugings.

TABLE No. 29.

Evaporation for Given Annual Precipitation on Sudbury, Croton and Passaic.

Annual Precipitation.	EVAPORATION.		
	Sudbury.	Croton.	Passaic.
31.55	20.15	....	....
38.52	....	....	20.97
39.40	21.32	....	....
40.07	....	21.40	....
43.49	....	....	20.38
43.97	21.66	....	....
44.42	....	22.13	....
46.30	....	....	22.19
46.39	22.85	....	....
47.06	....	23.77	....
50.05	....	22.72	....
50.85	23.62	....	....
52.33	23.53	....	....
55.98	24.01	....	....
61.70	....	....	24.80
70.88	....	... ...	25.65

The resemblance here is striking, and holds good for the closest analysis. The series are long and the character of the streams well known. As they all obey one law, and so closely resemble each other, we shall combine them in one formula, which we shall use for a starting point from which to work out to other streams which show somewhat different results. Charting the above values and adopting a line which represents a safe average of all, we obtain the following formula to express the relation between annual precipitation and annual evaporation on these streams:

$$E = 15.50 + .16\ R$$

In this and subsequent formulæ E equals annual evaporation, R equals annual rainfall and F equals annual flow, the latter being equal to R minus E.

A careful study of the annual precipitation and flow of the other streams, together with a number of the streams in the Mississippi basin, has practically demonstrated that the difference in amount discharged for given rainfalls is due almost entirely to increase or decrease of evaporation owing to increased or decreased annual temperature. The capacity of atmospheric air to absorb moisture is about doubled for each twenty degrees of increase in temperature. It is therefore safe to assume that the power of the atmosphere to draw moisture from the earth's surface is increased in like proportion, since statistics of evaporation from water surface, being much in excess of evaporation from earth, show clearly that the evaporation from land surface is never equal to the demand of the atmosphere for moisture. We will therefore allow for other water-sheds an increase or decrease of 5 per cent. from the values given by the above formula for evaporation on the Sudbury, Croton and Passaic, for each degree of increase or decrease of mean annual temperature from that of these three water-sheds, and compare the resulting evaporation with what has been actually shown as the result of gaugings.

TABLE No. 30.

Computed and Observed Annual Evaporation.

STREAM.	Mean temperature.	Mean annual precipitation.	Evaporation, computed as above.	Evaporation observed.
Sudbury, Croton and Passaic	49.7°	46.26	22.90	22.80
Neshaminy and Perkiomen	51.7°	49.96	25.85	25.96
Mississippi	52°	29.57	22.56	22.41
Upper Mississippi	48°	23.13	17.57	18.48
Missouri	48°	19.60	17.06	16.46
Red	60°	38.60	29.63	29.76
Ohio	55°	43.10	28.33	30.17
St. Croix	48°	30.00	18.60	18.90

The gaugings in the Mississippi basin are taken from the table compiled by James L. Greenleaf, C.E., and published in Vol. XVII., Part II., of the Tenth Census. They are from good sources, but not entirely accurate.

So far as we can tell from the data in hand, the formula which we have deduced from the gaugings of the Croton, Sudbury and Passaic holds good, therefore, allowing for temperature as above, for such extreme cases as 60 degrees mean annual temperature, or below 20 inches of mean annual precipitation. We have now introduced the element of mean annual temperature in order to make our formula applicable to all streams. Calling this T, a general formula for all streams would be as follows:

$$E = (15.50 + .16\,R)\,(1 + (T - 49.7)\,.05)$$
$$\text{or } E = (15.50 + .16\,R)\,(.05\,T - 1.48)$$

This, however, is merely a suggestion. Our purpose is to deduce laws which hold for our own State only. The above more extended examination, however, will serve to give confidence, inasmuch as it shows temperature and its consequent greater or less evaporation to be the controlling cause of divergence in the yield of different watersheds from a given rainfall.

While we could no doubt obtain more accurate results by incorporating the element of temperature in our formulæ of monthly flow, we prefer to avoid the complication which would result in actual application, inasmuch as we do not believe it is necessary or desirable to introduce so much refinement. Applying the above general formula, but carrying the results only to the nearest tenth, we obtain the following values of E for the water-sheds under examination.

TABLE No. 31.

Formulæ for Deducing Annual Evaporation from Annual Rainfall.

Sudbury, Croton, Passaic, Mean Annual Temperature, 49.7°, $E = 15.50 + .16\ R$
Connecticut, Mean Annual Temperature, 47°, $E = .9\ (15.50 + .16\ R)$
Tohickon, Neshaminy, Perkiomen, Mean Annual Temp., 51.7°, $E = 1.1\ (15.50 + .16\ R)$
Potomac, Mean Annual Temperature, 52°, $E = 1.1\ (15.50 + .16\ R)$

In none of these cases is the mean annual temperature so closely determined as to warrant greater accuracy than the nearest tenth. We think we have shown sufficiently well, however, that variation in temperature is the real cause of the variation of yield of the various streams above given, and a much more potent factor than forests, topography, or the other causes usually assigned to account for such variation. The facts of greater absorptive capacity of air when heated, of greater humidity of the atmosphere of southern localities, and the smaller relative yield of southern streams are all matters of general scientific observation.

Inasmuch as our term evaporation is comprehensive, including direct evaporation and the water absorbed and transpired by plant growth, the water available to produce stream-flow will be the difference between rainfall and evaporation, or $F = R - E$.

We have determined the relation between yearly rain, evaporation and flow. We have next to determine their distribution through the year. To this end we will first divide the year into two periods and observe the relation between rain, evaporation and flow for each.

TABLE No. 32.

Summer and Winter Rainfall, Flow and Evaporation.

DECEMBER TO MAY.			JUNE TO NOVEMBER.		
Rainfall.	Flow.	Evaporation.	Rainfall.	Flow.	Evaporation.
SUDBURY WATER-SHED.					
16.45	11.26	5.19	14.75	1.71	13.04
21.15	16.09	5.06	17.40	2.35	15.05
24.17	19.21	4.96	19.22	2.63	16.59
26.03	20.78	5.25	24.44	4.49	19.95
			27.68	6.99	20.69
			31.03	11.85	19.18
CROTON WATER-SHED.					
14.57	11.13	3.44	17.25	2.54	14.71
16.90	13.33	3.57	20.87	3.58	17.29
19.09	13.84	5.25	22.28	5.06	17.22
21.49	16.64	4.85	25.54	7.15	18.39
22.80	18.60	4.20	28.01	8.36	19.65
26.74	21.26	5.48			
PASSAIC WATER-SHED.					
18.79	14.33	4.46	15.88	3.62	12.26
20.56	15.65	4.91	20.20	3.53	16.67
21.69	16.75	4.94	22.83	5.16	17.67
25.29	20.25	5.04	23.98	6.34	17.64
28.30	22.52	5.78	25.64	8.26	17.38
			30.29	10.96	19.33
			45.69	20.44	25.25
TOHICKON WATER-SHED.					
22.70	18.25	4.45	20.87	4.65	16.22
26.82	22.87	3.95	26.19	6.78	19.41
			29.00	12.12	16.88
			45.25	26.15	19.10
NESHAMINY AND PERKIOMEN WATER-SHEDS.					
21.60	15.14	6.46	20.53	4.03	16.50
22.69	15.03	7.66	24.27	5.93	18.34
23.57	16.84	6.73	26.48	7.00	19.48
24.67	18.23	6.44	44.22	22.10	22.12
26.64	20.52	6.14			

Summer and Winter Rainfall, Flow and Evaporation—Continued.

POTOMAC WATER-SHED.

DECEMBER TO MAY.			JUNE TO NOVEMBER.		
Rainfall.	Flow.	Evaporation.	Rainfall.	Flow.	Evaporation.
18.70	11.06	7.64	19.56	4.58	14.98
24.00	13.60	10.40	21.51	5.67	15.84
....	....	....	22.62	7.54	15.08

CONNECTICUT WATER-SHED.

15.38	13.04	2.34	20.42	5.86	14.56
16.80	14.61	2.19	21.18	7.89	13.29
19.59	17.74	1.85	24.00	7.66	16.34
....	....	....	26.95	8.21	18.74
....	....	....	30.74	12.99	17.75

We find the resemblance between the Sudbury, Croton and Passaic holds good for these periods also. Following up this analysis in detail and platting the results, we find the year is best divided into two periods of six months each, of which one extends from December to May, showing small evaporation, which varies but little with the rainfall, and the other begins with June, extending through November, and showing large evaporation and a rapid increase, with increased rainfall. Platting and adopting a line to represent a rather high mean for these periods, we obtain the following formulæ for the Sudbury, Croton and Passaic:

$$\text{December to May, } E = 4.20 + .12\,R$$
$$\text{June to November, } E = 11.30 + .20\,R$$

In order to apportion this correctly between the months, I have, for the winter months, taken the distribution indicated in Table 17, since the conditions closely resemble evaporation from water surface. For the summer months, I find the best distribution to be an average between that for long and that for short grass in Table 14. Tested by the results shown by the gaugings themselves after frequent trials, I have found that with slight modification near the ends of the periods the distribution through the months thus obtained is accurate within the limits of our data.

TABLE No. 33.

Formulæ for Computing Monthly Evaporation from Monthly Rainfall.

SUDBURY, CROTON AND PASSAIC WATER-SHEDS.

e = Monthly Evaporation; r = Monthly Rainfall.

December	$e = .42 + .10\,r$
January	$e = .27 + .10\,r$
February	$e = .30 + .10\,r$
March	$e = .48 + .10\,r$
April	$e = .87 + .10\,r$
May	$e = 1.87 + .20\,r$
June	$e = 2.50 + .25\,r$
July	$e = 3.00 + .30\,r$
August	$e = 2.62 + .25\,r$
September	$e = 1.63 + .20\,r$
October	$e = .88 + .12\,r$
November	$e = .66 + .10\,r$
Year	$E = 15.50 + .16\,R$

It would be most reasonable to adapt these formulæ for other streams, by applying to each season a correction of five per cent. for each degree of difference of mean seasonal temperature above or below that for the same season on the above streams. Our temperature records, however, are not so complete or accurate as to make this advisable. We shall, for the limits of this inquiry, at least, obtain as good results if we assume the difference in mean annual temperature to be uniform throughout the seasons. To obtain the monthly evaporation for other streams, then, we apply to the results obtained from the above formulæ the following multipliers which we have already used: Connecticut, 0.8; Tohickon, Neshaminy, Perkiomen, 1.1; Potomac, 1.1, or in general, $.05\,T - 1.48$, in which T equals mean annual temperature. These formulæ are very readily applied so as to obtain the evaporation for any given rainfall in any month of the year.

Effect of Ground-Storage.

If we compute the evaporation as above for any of the drier years in our collection of gaugings, we shall find many months, and sometimes several in succession, in which evaporation equals or exceeds the rainfall. Let us, for example, take the Sudbury in 1882 and 1883. We have two dry periods giving the following results:

TABLE No. 34.

Supply to and Draught from Sudbury Water-shed During Dry Periods.

MONTH.	Observed rainfall.	Computed evaporation.	Observed flow.	Total supply = rainfall.	Total draught = evaporation + flow.
1882.					
June	1.66	2.91	.91	1.66	3.82
July	1.77	3.53	.15	3.43	7.40
August	1.67	3.04	.10	5.10	10.54
September	8.74	3.38	.53	13.84	14.45
October	2.07	1.13	.53	15.91	16.11
November	1.15	1.21	.36	17.06	17.68
December	2.30	.65	.56	19.36	18.89
1883.					
April	1.85	1.05	2.33	1.85	3.38
May	4.19	2.71	1.67	6.04	7.76
June	2.40	3.10	.52	8.44	11.38
July	2.68	3.80	.21	11.12	15.39
August	.74	2.80	.14	11.86	18.33
September	1.52	1.93	.16	13.38	20.42
October	5.60	1.55	.33	18.98	22.30
November	1.81	.84	.35	20.79	23.49
December	5.17	.94	1.65	25.96	26.08
January	4.71	.74	2.20	30.67	29.02

The first and the third columns of figures above are from observation. The second shows evaporation computed by our formulæ, the fourth shows the total rainfall from the beginning of the period, which is the supply of water to the water-shed, while the fifth shows the total drawn from the water-shed by evaporation and stream-flow combined. In the first period, it will be noted that the total draught exceeds the total supply throughout until December. By the end of August the excess has reached a maximum of 5.44 inches, and stream-flow has sunk to a minimum of .10 of an inch upon the water-shed. As the total supply approaches the total draught, in the last two columns, the flow increases. In the second period, August and September show a draught in excess of the supply over seven inches, and the stream-flow is again at a minimum. By January, the supply equals the total draught, and stream-flow has again reached about the amount with which we started, something over two inches. Whence has this excess of 5.44 inches in the first and 7.03 inches in the second case been drawn? Evidently, there is but one source, the stored ground-water. We have in the table itself the proof that there was great depletion of storage, for in September, 1882, rain amounting to 8.74 inches fell, and yet only .53 of an inch flowed off in the stream. Mr. Fitzgerald's table shows that not over 4.2 inches of this would have evaporated, even from a water surface. What became of the remainder? Evidently, it went to make up the amount which had been drawn from the ground. At the end of the first period, in December, the stream-flow should have been about two inches per month, but it was then winter. A part of the precipitation was held suspended in a frozen state, consequently the stream did not fully recover its normal flow for full ground-water. The end of the second period shows more clearly the rise of the stream to its normal flow, as the ground-water is replenished by rainfall, although here, also, the excess of supply over draught in December was probably in the form of snow or ice. The flow of the stream during such periods as these is almost entirely drawn from ground-storage and, like the flow from a constant outlet in any reservoir, it decreases as the water lowers in the reservoir, owing to a decrease of the head which forces it out, this decrease being first at a rapid rate, the rate diminishing as the reservoir approaches depletion. We learn, therefore, that when supply and draught are equal and ground-water is full, the flow of a stream will be the difference between rainfall and evaporation. We may warn the reader right here, however, that in freezing weather a portion of this theoretical flow may be held back as snow or ice, and carried over to increase the flow of later months when it melts. Further, a part of the rainfall recorded as of a given month may fall so late as to not fully affect the stream until the first of the subsequent

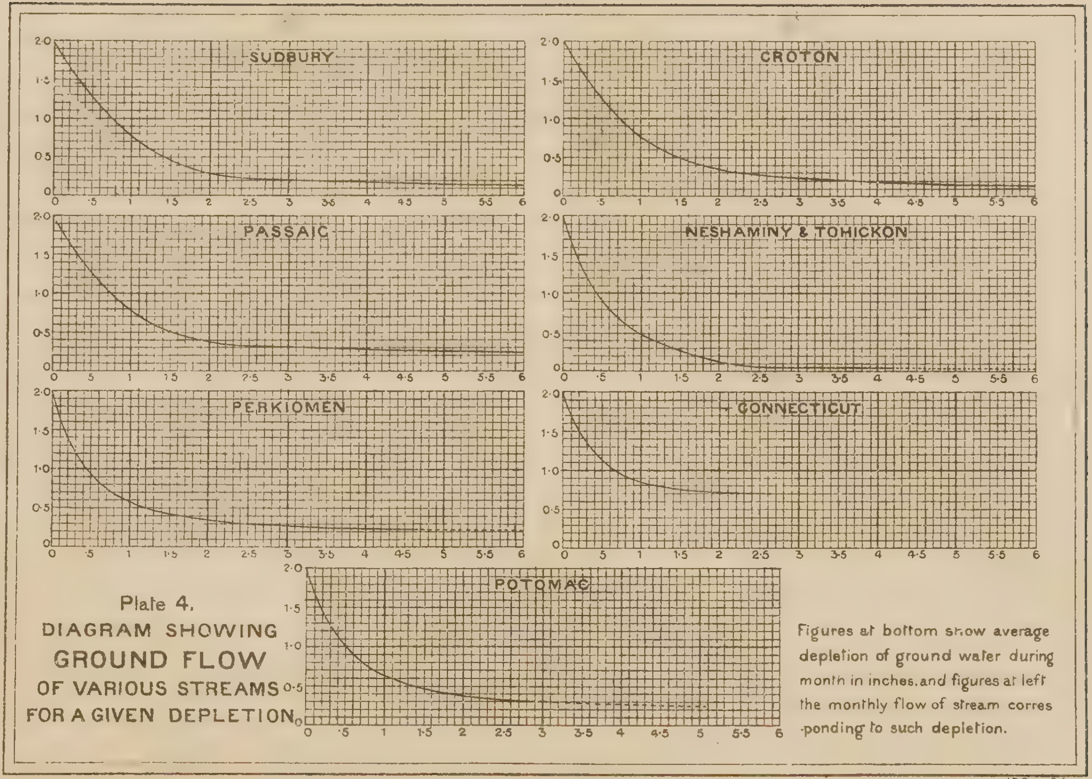

Plate 4.
DIAGRAM SHOWING
GROUND FLOW
OF VARIOUS STREAMS
FOR A GIVEN DEPLETION.

Figures at bottom show average depletion of ground water during month in inches, and figures at left the monthly flow of stream corresponding to such depletion.

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month. There is no way to provide for these accidental variations in our formulæ, nor do they practically affect the value of the formulæ although due allowance should be made for them when we come to compare theoretical, computed flow with flow actually observed During months like those in the above table, however, in which flow is from ground-storage, it is necessary for us to determine for each stream the rate of monthly flow for given stages of depletion of ground-water, before we can compute the dry-season flow of such a stream. This is readily done from the gaugings by an analysis similar to the last table. Thus for August, 1882, the depletion at the end of July was 3.97 and at the end of August 5.44 inches, the average being 4.70 inches, and the corresponding stream-flow is .10 inch on the water-shed for the month. Analyzing any set of gaugings in this manner and platting the results, we can construct a curve of ground-water flow, like those produced herewith.

In all these analyses the flow for full ground-water seems to range close to two inches per month, and I have assumed this in every case. The resemblance between the Sudbury, Croton and Passaic is marked for high ground-water, but for lower stages the Passaic shows the best-sustained flow, the Croton coming next. In every case the flow approaches a constant as the surface of the ground-water approaches the slope, at which the pressure toward the point of delivery is nearly equaled by the friction of the material through which the water flows. In similar soils, or those of about the same density, the delivery of ground-water is more rapid as the range of elevation of the surface of the water-shed increases, *i. e.* where there is the boldest relief. Given the same relief, the delivery is greater for material presenting the most voids; clay, loam, sand and gravel ranging in the order named.

HOW TO COMPUTE FLOW.

Applying the above facts, we may compute the flow of a stream by months for any given year of which we have the rainfall recorded by months. First we enter the observed rainfall as in Table No. 35, and beginning with December for reasons already considered. In the next column we enter the total rainfall from the beginning of the year to the end of the given month. Next having the mean annual temperature, T, we determine $1 + (T - 49.7^\circ)\ .05$, the factor by which evaporation as found for each month by the formulæ of Table

No. 33 is to be multiplied in order to give the true evaporation for the stream in question. Computing this evaporation for each month we enter it in the third column of figures, the total from the beginning being entered in column four.

Beginning with December, we may now take the monthly flow as equal to the difference between rainfall and evaporation until such difference becomes less than the ground-flow due to full ground-water, or about two inches. When the difference falls much below this point, our ground-flow diagram is brought into requisition. This we must have prepared with the aid of gaugings, or, lacking these, we must adopt the diagram of some similar water-shed. We have entered our monthly flow in the fifth and its total in the sixth column. So long as the total rainfall in the second column equals the total evaporation plus the total flow, the ground-water remains full at the end of the month. So soon as the surplus of rain over evaporation is less than the amount which the ground of the water-shed will deliver into the stream, a deficiency will occur, ground-water will lower, "wet-weather springs" will begin to dry up. We must now seek a monthly flow which will be such as to correspond to the average condition of the ground-water during the month. Calling the depletion at end of previous month, shown in column seven, d_1, and that for the month under consideration, d_2, we have $d_2 = d_1 + e + f - r$. The average depletion for the month, or $d = \frac{d_1 + d_2}{2} = d_1 + \frac{e - r}{2} + \frac{f}{2}$, or more conveniently $d = \frac{f}{2} + d_1 - \frac{r - e}{2}$. Here all are known quantities excepting f. In our example April is the month under consideration, $d_1 = o$, $r = 1.82$ and $e = 1.05$. Substituting, we have $d = \frac{f}{2} - .38$ for the condition to be satisfied. An inspection of the ground-flow diagram of the Sudbury shows that for $f = 1.44$, $d = .34$, which satisfies the above conditions. With a little practice, one or two mental trials will fix the value of f with slight effort. The diagrams present advantages over a ground-flow formula with varying constants and co-efficients for different streams, being more readily compared and insuring greater accuracy. It should be noted that f can in no case be less than $r - e - d_1$, for the rain of a month goes partly into the ground to replace depletion at the beginning of the month, partly to evaporation and the balance must flow off in the stream, although it may be held back in the form of snow or ice to flow off in a later month.

The examples here given are intended also to indicate how the computed and observed flows of streams compare.

TABLE No. 35.

Computed and Observed Flow, Sudbury River.

MONTH.	Monthly rainfall = r.	Total rainfall = R.	Monthly evaporation = e.	Total evaporation = E.	Computed monthly flow = f.	Computed total flow = F.	Depletion of ground-water = $R - E - F$.	Observed monthly flow.	Observed total flow.
1881-2.									
December	3.96	3.96	.79	.79	3.17	3.17	full.	*2.79	2.79
January	5.95	9.91	.87	1.66	5.08	8.25	full.	2.21	5.00
February	4.55	14.46	.75	2.41	3.80	12.05	full.	3.87	8.87
March	2.65	17.11	.74	3.15	1.91	13.96	full.	5.06	13.93
April	1.82	18.93	1,05	4.20	1.44	15.40	.67	1.50	15.43
May	5.07	24.00	2.88	7.08	1.52	16.92	full.	2.30	17.73
June	1.66	25.66	2.91	9.99	.82	17.74	2.07	.91	18.64
July	1.77	27.43	3.53	13.52	.20	17.94	4.03	.15	18.79
August	1.67	29.10	3.04	16.56	.15	18.09	5.55	.10	18.89
September	8.74	37.84	3.38	19.94	.20	18.29	.39	.53	19.42
October	2.07	39.91	1.13	21.07	1.28	19.57	.73	.53	19.95
November	1.15	41.06	1.21	22.28	.73	20.30	1.52	.36	20.31
1882-3.									
December	2.30	43.36	.65	22.93	.72	21.02	.59	.56	20.87
January	2.81	46.17	.55	23.48	1.67	22.69	full.	.60	21.47
February	3.87	50.04	.68	24.16	3.19	25.88	full.	1.66	22.13
March	1.78	51.82	.66	24.82	1.12	27.00	full.	2.87	26.00
April	1.85	53.67	1.05	25.87	1.52	28.52	.72	2.33	28.33
May	4.19	57.86	2.71	28.58	1.24	29.76	.48	1.67	30.00
June	2.40	60.26	3.10	31.68	.70	30.46	1.88	.52	30.52
July	2.68	62.94	3.80	35.48	.23	30.69	3.23	.21	30.73
August	0.74	63.68	2.80	38.28	.16	30 85	5.45	.14	30.87
September	1.52	65.20	1.93	40.21	.14	30.99	6 00	.16	31.03
October	5.60	70.80	1.55	41.76	.27	31.26	2.22	.33	31.36
November	1.81	72.61	.84	42.60	.38	31.64	1.63	.35	31.71

* Corrected for deficiency of 1.41 from previous year.

Summary by Seasons, Sudbury River.

	1881–2.			1882–3.		
	Rainfall.	Computed Flow.	Observed Flow.	Rainfall.	Computed Flow.	Observed Flow.
Winter	14.46	12 05	8.87	8.98	5.58	2.82
Spring	9.54	4.87	8.86	7.82	3.88	6.87
December to May	24.00	16.92	17.73	16.80	9.46	9.69
Summer	5.10	1.17	1.16	5.82	1.09	.87
Autumn	11.96	2.21	1.42	8.93	.79	.84
June to November	17.06	3.38	2.58	14.75	1.88	1.71
Year	41.06	20.30	20.31	31.55	11.34	11.40

Our winter-computed flows are generally larger than the observed, as they include snow and ice carried over into the spring. No formula can make proper allowance for this. It varies with every winter, and we can only say that with full ground-water the flow will not usually fall lower than one-half the theoretical, and rarely in any case will the monthly flow in this season fall below half an inch on the water-shed. The extremely light winter flow of 1882–3 on the Sudbury was due to a combination of freezing weather, snow and ice and low ground-water. At the close of April the observed flow equals the theoretical. The actual winter flow is about 50 per cent. of the theoretical. The difference would be the equivalent of 27 inches of snow, or a less amount accompanied by ice. The actual amount held back as snow or ice in New Jersey can rarely exceed three inches. From December to May the computed and observed total flows agree well. For the first year I have corrected the December observed flow to allow for 1.41 inches of water which would have flowed off had it not gone to make good a depletion of that amount of ground-water at the end of November. This method of computation often links two years together in this way, and for illustration of this I have computed the two years above continuously. This shows how the year 1882–3 began with a shortage of 1.52 inches from the previous year, and ended with a depletion of

1.63 inches, about the same amount. The flow of 11.40 inches for 31.55 inches of rain was therefore about normal, or more exactly it should be 11.63, showing evaporation to be 19.72. Our formula $E = 15.50 + .16\,R$ gives $E = 20.55$ inches, or somewhat larger. The reason is that the heavier rainfall was in the summer and spring, the seasons of maximum evaporation.

TABLE No. 36.

Computed and Observed Flow, Croton River.

MONTH.	Monthly rainfall = r.	Total rainfall = R.	Monthly evaporation = e.	Total evaporation = E.	Computed monthly flow = f.	Computed total flow = F.	Depletion of ground-water = $R - E - F$.	Observed monthly flow.	Observed total flow.
1879-80.									
December	4.08	4.08	.83	.83	1.88	1.88	full.	1.88	1.88
January	3.80	7.88	.65	1.48	3.15	5.03	full.	2.62	4.50
February	2.97	10.85	.60	2.08	2.37	7.40	full.	2.75	7.25
March	4.01	14.86	.88	2.96	3.13	10.53	full.	2.89	10.14
April	3.57	18.43	1.23	4.19	2.34	12.87	full.	1.96	12.10
May	1.09	19.52	2.09	6.28	.82	13.69	—1.82	.85	12.95
June	1.06	20.58	2.77	9.05	.25	13.94	—3.78	.37	13.32
July	5.57	26.15	4.67	13.72	.22	14.16	—3.10	.35	13.67
August	3.82	29.97	3.57	17.29	.24	14.40	—3.09	.24	13.91
September	2.50	32.47	2.33	19.62	.24	14.64	—3.16	.25	14.16
October	2.75	35.22	1.21	20.83	.27	14.91	—1.89	.20	14.36
November	2.39	37.61	.90	21.73	.52	15.43	— .92	.42	14.78
1880-1.									
December	2.44	2.44	.66	.66	.86	.86	full.	.47	.47
January	4.86	7.30	1.00	1.66	3.86	4.72	full.	.59	1.06
February	4.96	12.26	.80	2.46	4.16	8.88	full.	2.92	3.98
March	6.15	18.41	1.09	3.55	5.06	13.94	full.	5.42	9.40
April	1.24	19.65	.99	4.54	1.25	15.19	—1.00	1.69	11.09
May	3.46	23.11	2 26	6.80	1.23	16.42	—1.03	1.26	12.35
June	5.05	28.16	3.76	10.56	1.25	17.67	— .99	1.46	13.81
July	2.07	30.23	3.62	14.18	.35	18.02	—2.89	.47	14.28
August	2.66	32.89	3.28	17.46	.22	18.24	—3.73	.23	14.51
September	.70	33.59	1.77	19.23	.18	18.42	—4 98	.14	14.65
October	2.79	36.38	1.21	20.44	.18	18.60	—3.58	.19	14.84
November	5.21	41.59	1.18	21.62	.38	18.98	— .07	.50	15.34

Computed and Observed Flow, Croton River—Continued.

MONTH.	Monthly rainfall = r.	Total rainfall = R.	Monthly evaporation = e.	Total evaporation = E.	Computed monthly flow = f.	Computed total flow = F.	Depletion of ground-water = $R - E - F$.	Observed monthly flow.	Observed total flow.
1871–2.									
December	2.59	2.59	.68	.68	1.91	1.91	full.	2.10	2.10
January	1.44	4.03	.41	1.09	1.03	2.94	full.	1.88	3.98
February	1.22	5.25	.42	1.51	.80	3.74	full.	1.07	5.05
March	2.59	7.84	.74	2.25	1.85	5.59	full.	1.31	6.36
April	3.04	10.88	1.17	3.42	1.87	7.46	full.	2.97	9.33
May	3.69	14.57	2.61	6.03	1.57	9.03	— .49	1.20	10.53
June	4.00	18.57	3.50	9.53	.98	10.01	— .97	1.14	11.67
July	4.34	22.91	4.30	13.83	.61	10.62	—1.54	.55	12.22
August	5.99	28.90	4.12	17.95	.79	11.41	— .46	1.24	13.46
September	3.69	32.59	2.37	20.32	1.30	12.71	— .44	1.13	14.59
October	2.15	34.74	1.13	21.45	1.21	13.92	— .63	1.07	15.66
November	4.91	39.65	1.15	22.60	3.13	17.05	full.	2.48	18.14

Summary by Seasons.

	1879–80.			1880-1.			1871-2.		
	Rainfall.	Computed flow.	Observed flow.	Rainfall.	Computed flow.	Observed flow.	Rainfall.	Computed flow.	Observed flow.
Winter	10.85	7.40	7.25	12.26	8.88	3.98	5.25	3.74	5.05
Spring	8.67	6.29	5.70	10.85	7.54	8.37	9.32	5.29	5.48
Dec. to May	19.52	13.69	12.95	23.11	16.42	12.35	14.57	9.03	10.53
Summer	10.45	.71	.96	9.78	1.82	2.16	14.33	2.38	2.93
Autumn	7.64	1.03	.87	8.70	.74	.83	10.75	5.64	4.68
June to Nov.	18.09	1.74	1.83	18.48	2.56	2.99	25.08	8.02	7.61
Year	37.61	15.43	14.78	41.59	18.98	15.34	39.65	17.05	18.14

NOTE.—The rainfall in this table has been carefully corrected, and differs slightly from that of Table 22.

As we should expect from the nature of the gaugings and the unsatisfactory rainfall records, the agreement is less satisfactory on the Croton, but there are, nevertheless, convincing evidences of the correctness of our formula. For 1879–80, the excess of computed over observed winter and spring flow is to be accounted for by the filling of storage reservoirs. We have corrected the monthly flow in summer for this and the following year for water drawn from storage, deducting the same, but we have no data by which to determine the amount to be added to winter and spring flow except that we know it amounted to 1.40 inches on the water-shed in the aggregate. The summer and autumn of 1880 show a good agreement between computed and observed flow. The winter and spring of 1880–1 show a large excess of computed flow, 1.4 inches of which is due to artificial storage, leaving an excess of 2.7 inches still unaccounted for. The general agreement for the whole series with the results given by the formula justifies the conclusion that this is either error in gauging or rainfall. A generally fair agreement is noted for the rest of the year.

TABLE No. 37.

Computed and Observed Flow of Passaic River.

MONTH.	Monthly rainfall $= r$.	Total rainfall $= R$.	Monthly evaporation $= e$	Total evaporation $= E$.	Computed monthly flow $= f$.	Computed total flow $= F$.	Depletion of ground-water $= R - E - F$.	Observed monthly flow.	Observed total flow.
1879-80.									
December	5.04	5.04	0.92	0.92	4.12	4.12	full.	2.42	2.42
January	2.40	7.44	.51	1.43	1.89	6.01	full.	3.55	5.97
February	2.72	10.16	.57	2.00	2.15	8.16	full.	2.64	8.61
March	4.12	14.28	.89	2.89	3.23	11.39	full.	2.55	11.16
April	2.89	17.17	1.16	4.05	1.73	13.12	full.	2.09	13.25
May	.61	17.78	1.99	6.04	.74	13.86	—2.12	1.04	14.29
June	1.44	19.22	2.86	8.90	.31	14.17	—3.85	.32	14.61
July	7.69	26.91	5.31	14.21	.32	14.49	—1.79	.42	15.03
August	4.87	31.78	3.84	18.05	.50	14.99	—1.26	.50	15.53
September	2.18	33.96	2.07	20.12	.55	15.54	—1.70	.48	16.01
October	1.70	35.66	1.08	21.20	.47	16.01	—1.55	.22	16.23
November	2.32	37.98	.89	22.09	.65	16.66	— .77	.74	16.97

Computed and Observed Flow of Passaic River—Continued.

MONTH.	Monthly rainfall = r.	Total rainfall = R.	Monthly evaporation = e.	Total evaporation = E.	Computed monthly flow = f.	Computed total flow = F.	Depletion of ground-water = $R - E - F$.	Observed monthly flow.	Observed total flow.
1880–1.									
December	2.70	40.68	.69	22.78	1.24	17.90	full.	.68	17.65
January	4.08	44.76	.68	23.46	3.40	21.30	full.	1.14	18.79
February	4.57	49.33	.76	24.22	3.81	25.11	full.	3.59	22.38
March	5.10	54.43	.99	25.21	4.11	29.22	full.	6.77	29.15
April	1.04	55.47	.97	26.18	1.20	30.42	—1.13	1.68	30.83
May	2.78	58.25	1.42	27.60	.90	31.32	— .67	.89	31.72
June	5.42	63.67	3.85	31.45	1.25	32.57	— .35	1.89	33.61
July	1.85	65.52	3.56	35.01	.52	33.09	—2.58	.39	34.00
August	.90	66.42	2.84	37.85	.28	33.37	—4.80	.27	34.27
September	1.06	67.48	1.84	39.69	.25	33.62	—5.83	.26	34.53
October	3.08	70.56	1.25	40.94	.25	33.87	—4.25	.25	34.78
November	3.12	73.68	.97	41.91	.30	34.17	—2 40	.57	35.35
December	4.59	78.27	.88	42.79	1.31	35.48	full.	1.65	37.00
1890.									
January	2.69	2.69	.54	.54	2.15	2.15	....	2.01	2.01
February	4.59	7.28	.76	1.30	3.83	5.98	....	3.24	5.25
March	6.03	13.31	1.08	2.38	4.95	10.93	....	3.30	8.55
April	2.58	15.89	1.13	3.51	1.45	12.38	....	2.99	11.54
May	4.39	20.28	2.75	6.26	1.64	14.02	....	2.74	14.28
June	4.55	24.83	3.64	9.90	1.50	15.52	— .43	1.78	16.06
July	6.14	30.97	4.84	14.74	1.26	16.78	— .55	1.47	17.53
August	4.96	35.93	3.86	18.60	1.15	17.93	— .60	1.04	18.57
September	3.73	39.66	2.38	20.98	1.21	19.14	— .46	1.52	20.09
October	5.20	44.86	1.50	22.48	3.24	22.38	....	2.49	22.58
November	.75	45.61	.73	23.21	1.16	23.54	—1.14	1.37	23.95
December	4.17	49.78	.84	24.05	2.19	25.73	....	1.98	25.93

Summary by Seasons.

	1879–80.			1880–1.			1890.		
	Rainfall.	Computed flow.	Observed flow.	Rainfall.	Computed flow.	Observed flow.	Rainfall.	Computed flow.	Observed flow.
Winter............	10.16	8.16	8.61	11.35	8.45	5.41	11.45	8.17	7.23
Spring	7.62	5.70	5.68	8.92	6.21	9.34	13.00	8.04	9.03
Dec. to May...	17.78	13.86	14.29	20.27	14.66	14.75	24.45	16.21	16.26
Summer...........	14.00	1.13	1.24	8.17	2.05	2.55	15.63	3.91	4.29
Autumn	6.20	1.67	1.44	7.26	.80	1.08	9.68	5.61	5.38
June to Nov...	20.20	2.80	2.68	15.43	2.85	3.63	25.33	9.52	9.67
Year	37.98	16.66	16.97	35.70	17.51	18.38	49.78	25.73	25.93

In this case the summary shows a fair agreement, the estimated flow usually being a little less than the observed, therefore on the safe side. In 1880–1, which was a dry year, the winter flow is 3.04 inches less than the computed flow, this amount being carried over in the form of snow and ice to increase the spring flow. The other years show much smaller discrepancies, but it is apparent that it is always possible that three inches of the theoretical winter flow may be carried over to the spring, even in the driest years, in northern New Jersey.

We observe for all of these streams that our formula holds good in some remarkably trying cases. Bearing in mind what we have said as to accidental variations of flow which cannot be provided for, it will be found that in general the same range of flow, the same trying dry periods and heavy flows are shown in the computed as in the observed monthly flow. For instance, in Table No. 35, September, 1882, shows 8.74 inches rainfall, yet the observed flow was but .53 inch. The table explains all this. No system of percentages would do so much. In this particular case the observed flow is larger than the computed, because some of the rapidly-falling rain, about 4 per cent., ran off over the surface. So in June of the same year we can account for 1.66 inches of rain and .82 inch flow in the face of the 2.91 inches evaporation by the fact that ground-water was called upon to supply 2.07 inches.

Another striking test of the tables is in April, 1881, on the Croton —1.25 inches flow for 1.24 inches rain—and again on the Passaic, in May, 1880. By the percentage system such cases wóuld appear anomalous. Here they are intelligible. We could give many more illustrations, but this must suffice to explain why we have adopted a new departure in our methods of computing flow.

We note a maximum depletion of 6 inches in 1883 on the Sudbury, of 4.98 inches on the Croton in 1881, and 5.83 on the Passaic in 1881. Probably either water-shed may be counted upon to furnish something over 6 inches from ground-water in an extremely dry year. Evidently all are liable to droughts as severe as that on the Sudbury in 1882–3, at long intervals.

As our formula was deduced primarily from these three streams, it would seem necessary to push our tests further to include some water-sheds of different mean annual temperature and different topography. The gaugings on the Neshaminy and Perkiomen are about the only ones suitable for a fair test, but others may at least be indicative of the probable applicability of the method.

TABLE No. 38.

Computed and Observed Flow, Neshaminy Creek.

EVAPORATION EQUALS THAT FOR THE SUDBURY, CROTON AND PASSAIC MULTIPLIED BY 1.1.

MONTH.	Monthly rainfall = *r.*	Total rainfall = *R.*	Monthly evaporation = *e.*	Total evaporation = *E.*	Computed monthly flow = *f.*	Computed total flow = *F.*	Depletion of ground-water = *R* — *E* — *F.*	Observed monthly flow.	Observed total flow.
1888-9.									
December	3.72	3.72	.87	.87	2.85	2.85	full.	3.16	3.16
January	3.61	7.33	.69	1.56	2.92	5.77	full.	2.92	6.08
February	1.90	9.23	.54	2.10	1.36	7.13	full.	.90	6.98
March	3.37	12.60	.90	3.00	2.47	9.60	full.	2.90	9.88
April	4.83	17.43	1.48	4.48	3.35	12.95	full.	2.07	11.95
May	4.90	22.33	3.15	7.63	1.75	14.70	full.	1.49	13.44
June	5.25	27.58	4.19	11.82	1.06	15.76	full.	1.16	14.60
July	12.42	40.00	7.39	19.21	5.03	20.79	full.	5.47	20.07
August	4.75	44.75	4.19	23.40	1.18	21.97	—.62	3.37	23.44
September	8 56	53.31	3.67	27.07	4.27	26.24	full.	3.51	26.95
October	5.09	58.40	1.64	28.71	3.45	29.69	full.	2.55	29.50
November	8.53	66.93	1.66	30.37	6.87	36.56	full.	6·31	35.81

Computed and Observed Flow, Neshaminy Creek—Continued.

MONTH.	Monthly rainfall = r.	Total rainfall = R.	Monthly evaporation = e.	Total evaporation = E.	Computed monthly flow = f.	Computed total flow = F.	Depletion of ground-water = $R - E - F$.	Observed monthly flow.	Observed total flow.
1891-2.									
December	4.19	4.19	.92	.92	3.27	3.27	full.	3.02	3.02
January	5.09	9.28	.86	1.78	4.23	7.50	full.	5 14	8.16
February	1.06	10.34	1.46	3.24	.78	8.28	—1.18	.97	9.13
March	4.13	14.47	.98	4.22	1.97	10.25	full.	3.56	12.69
April	2.24	16.71	1.20	5.42	1.04	11.29	full.	1.03	13.72
May	5.83	22.54	3.34	8.76	2.49	13.78	full.	1.28	15.00
June	3.38	25.92	3.67	12.43	.82	14.60	—1.11	.57	15.57
July	4.83	30.75	4.78	17.21	.34	14.94	—1.40	.53	16.10
August	3.37	34.12	3.81	21.09	.19	15.13	—2.10	.20	16.30
September	2.59	36.71	2.36	23.45	.10	15.23	—1.97	.10	16.40
October	.40	37.11	1.02	24.47	.04	15.27	—2.69	.04	16.44
November	7.14	44.25	1.51	25.98	3.00	18.27	full.	1.76	18.20

Summary by Seasons, Neshaminy Creek.

	1888-9.			1891-2.		
	Rainfall.	Computed flow.	Observed flow.	Rainfall.	Computed flow.	Observed flow.
Winter	9.23	7.13	6.98	10.34	8.28	9.13
Spring	13.10	7.57	6.46	12.20	5.50	5.87
December to May	22.33	14.70	13.44	22.54	13.78	15.00
Summer	22.42	7.27	10.00	11.58	1.36	1.30
Autumn	22.18	14.59	12.37	10.13	3.13	1.90
June to November	44.60	21.86	22.37	21.71	4.49	3.20
Year	66.93	36.56	35.81	44.25	18.27	18.20

TABLE No. 39.

Observed and Computed Flow, Perkiomen Creek.

EVAPORATION EQUALS THAT FOR THE SUDBURY, CROTON AND PASSAIC MULTIPLIED BY 1.1.

MONTH.	Monthly rainfall = *r*.	Total rainfall = *R*.	Monthly evaporation = *e*.	Total evaporation = *E*.	Computed monthly flow = *f*.	Computed total flow = *F*.	Depletion of ground-water.	Observed monthly flow.	Observed total flow.
1886-7.									
December	3.76	3.76	.88	.88	2.88	2.88	full.	*2.43	2.43
January	4.55	8.31	.79	1.67	3.76	6.64	full.	4.00	6.43
February	5.64	13.95	.95	2.62	4.69	11.33	full.	4.23	10.66
March	3.00	16.95	.86	3.48	2.14	13.47	full.	3.03	13.69
April	2.84	19.79	1.26	4.74	1.58	15.05	full	1.25	14.94
May	1.85	21.64	2.46	7.20	.74	15.79	—1.35	.72	15 66
June	5.87	27.51	4.37	11.57	.60	16.39	— .45	.76	16.42
July	8.63	36.14	6.15	17.72	2.03	18.42	full.	2.07	18.49
August	2.76	38.90	3.64	21.36	.66	19.08	—1 54	1.43	19.42
September	3.64	42.54	2.60	23.96	.46	19.54	— .96	.62	20.54
October	1.44	43.98	1.15	25.11	.54	20.08	—1.21	.43	20.97
November	1.61	45.59	.90	26.01	.50	20.58	—1.00	.40	21.37
1887-8.									
December	6.65	52.24	1.20	27.21	4.45	25.03	full.	2.13	23.50
January	5.01	57.25	.85	28.06	4.16	29.19	full.	3.66	27.16
February	4.08	61.33	.78	28.84	3.30	32.49	full.	4.41	31.57
March	5.15	66.48	1.10	29.94	4.05	36.54	full.	5.10	36.67
April	3.43	69.91	1.33	31.27	2.10	38.64	full.	3.45	40.12
May	3.16	73.07	2.75	34.02	1.10	39.74	.69	.92	41.04
June	1.62	74.69	3.19	37.21	.40	40.14	2.66	.39	41.43
July	2.77	77.46	4.21	41.42	.24	40.38	4.34	.25	41.68
August	8.02	85.48	5.09	46.51	.26	40.64	1.67	1.53	43.21
September	7.36	92.84	3.41	49.92	2.28	42.92	full.	3.68	46.89
October	3.41	96.25	1.29	51.21	1.12	44.04	full.	1.26	48.15
November	3.42	99.67	1.10	52.31	2.32	46.36	full.	2.46	50.61

* Corrected for one inch of rain which went to make up deficiency of previous year.

Summary by Seasons, Perkiomen Creek.

	1886–7.			1887–8.		
	Rainfall.	Computed flow.	Observed flow.	Rainfall.	Computed flow.	Observed flow.
Winter	13.95	11.33	10.66	15.74	11.91	10.20
Spring	7.69	4.46	5.00	11.74	7.25	9.47
December to May	21.64	15.79	15.66	27.48	19.16	19.67
Summer	17.26	3.29	4.26	12.41	.90	2.17
Autumn	6.69	1.50	1.45	14.19	5.72	7.40
June to November	23.95	4.79	5.71	26.60	6.62	9.57
Year	45.59	20.58	21.37	54.08	25.78	29.24

I do not give an example from the Tohickon. Its ground-flow is practically the same as the Neshaminy, which it closely resembles in the dry seasons. Its gaugings in winter show abnormally heavy flow, indicating uncertain data either as to rainfall or flow. A rule which will apply to the Neshaminy applies equally well to this.

The computed flows of the Neshaminy in 1888–9, a very wet year, agree well enough for the total, with some marked discrepancies at times which appear to be due to rainfall running off without filling the ground. It is a peculiarity of the red shale soil that it sometimes becomes baked by the sun in summer, and at such times a highly-concentrated rainfall may run off without "filling the springs," as the ordinary phrase expresses it. In such cases the ground-water must be replenished by the later rains, and the theoretical and actual flow will again come together. For the average year of 1891–2 the results are on the safe side, and show the same general range as the observed flows. For the Perkiomen the results are in all cases on the safe side for the two consecutive years, 1886–7–8. Indeed, it will be found that generally the errors of the formula are on the side of safety. It is not safe for the engineer or millwright to depend upon flows which may be called accidental, due to concentrated rainfall, low summer temperature or perhaps heavy local showers not recorded by the rain-gauges. It is the regular, steady flow resulting from a steadily-falling rain, or from ground-water flow, which is useful to them.

TABLE No. 40.

Computed and Observed Flow, Potomac River.

EVAPORATION EQUALS THAT FOR THE SUDBURY, CROTON AND PASSAIC MULTIPLIED BY 1.1.

MONTH.	Monthly rainfall = r.	Total rainfall = R.	Monthly evaporation = e.	Total evaporation = E.	Computed monthly flow = f.	Computed total flow = F.	Depletion of ground-water.	Observed monthly flow.	Observed total flow.
1886–7.									
December	2.60	2.60	.73	.73	1.87	1.87	full.	1.14	1.14
January	2.38	4.98	.55	1.28	1.83	3.70	full.	1.27	2.41
February	3.88	8.86	.75	2.03	3.13	6.83	full.	2.28	4.69
March	2.86	11.72	.83	2.86	2.03	8.86	full.	2.84	7.53
April	3.56	15.28	1.33	4.19	2.23	11.09	full.	1.42	8.95
May	3.51	18.79	2.77	6.96	1.30	12.39	.56	2.62	11.57
June	4.44	23.23	3.90	10.86	.76	13.15	.78	1.43	13.00
July	5.04	28.27	4.87	15.73	.70	13.85	1.31	.64	13.64
August	2.17	30.44	3.42	19.15	.42	14.27	2.98	.37	14.01
September	3.58	34.02	2.54	21.69	.30	14.57	2.24	.37	14.38
October	1.21	35.23	1.11	22.80	.34	14.91	2.48	.35	14.73
November	1.17	36.40	.84	23.64	.32	15.23	2.47	.33	15.06
1887-8.									
December	3.23	39.63	.81	24.45	.45	15.68	.50	.58	15.64
January	3.27	42.90	.66	25.11	2.11	17.79	full.	1.33	16.97
February	2.71	45.61	.63	25.74	2.08	19.87	full.	2.70	19.67
March	3.68	49.29	.93	26.67	2.75	22.62	full.	3.01	22.68
April	2.01	51.30	1.18	27.85	1.36	23.98	.53	1.82	24.50
May	3.71	55.01	2.87	30.72	.92	24.90	.61	1.11	25.61
June	3.40	58.41	3.68	34.40	.60	25.50	1.49	.88	26.49
July	3.65	62.06	4.42	38.82	.36	25.86	2.62	1.94	28.43
August	4.78	66.84	4.10	42.92	.32	26.18	2.26	.51	28.94
September	5.34	72.18	2.97	45.89	.49	26.67	.38	1.70	30.64
October	2.74	74.92	1.33	47.22	1.36	28.03	.33	.74	31.38
November	3.09	78.01	1.07	48.29	1.69	29.72	full.	1.66	33.04

Summary by Seasons, Potomac River.

	1886–7.			1887–8.		
	Rainfall.	Computed flow.	Observed flow.	Rainfall.	Computed flow.	Observed flow.
Winter	8.86	6.83	4.69	9.21	4.64	4.61
Spring	9.93	5.56	6.88	9.40	5.03	5.94
December to May	18.79	12.39	11.57	18.61	9.67	10.55
Summer	11.65	1.88	2.44	11.83	1.28	3.33
Autumn	5.96	.96	1.05	11.17	3.54	4.10
June to November	17.61	2.84	3.49	23.00	4.82	7.43
Year	36.40	15.23	15.06	41.61	14.49	17.98

With the exception of the winters of 1889–90 and 1890–91, and the summer of 1889, which show such questionably large flows in proportion to rainfall that I have disregarded them, the series on the Potomac seem to come under the rule very well. The above are the driest years. 1886–7 shows an excellent agreement throughout. 1887–8 shows a considerable excess of observed over computed flow in July and September, which may be due to heavy local rains not shown by the rainfall records. Undoubtedly, our formula applies here within safe limits, and gives results as large as any conservative hydraulic engineer would dare to apply to actual practice.

TABLE No. 41.

Observed and Computed Flow, Connecticut River.

EVAPORATION EQUALS THAT FOR THE SUDBURY, CROTON AND PASSAIC MULTIPLIED BY .9.

MONTH.	Monthly rainfall = r.	Total rainfall = R.	Monthly evaporation = e.	Total evaporation = E.	Computed monthly flow = f.	Computed total flow = F.	Depletion of ground-water.	Observed monthly flow.	Observed total flow.
1874-5.									
December	1.82	1.82	.54	.54	1.28	1.28	full.	.76	.76
January	3.40	5.22	.55	1.09	2.85	4.13	full.	.72	1.48
February	2.95	8.17	.54	1.63	2.41	6.54	full.	1.14	2.62
March	3.18	11.35	.72	2.35	2.46	9.00	full.	2.06	4.68
April	2.54	13.89	1.01	3.36	1.53	10.53	full.	6.14	10.82
May	3.24	17.13	2.27	5.63	1.44	11.97	.47	4.69	15.51
June	4.80	21.93	3.33	8.96	1.32	13.29	.32	1.50	17.01
July	3.50	25.43	3.65	12.61	.93	14.22	1.40	.97	17.98
August	4.84	30.27	3.45	16.06	.81	15.03	.82	1.35	19.33
September	3.03	33.30	2.02	18.08	.92	15.95	.73	.74	20.07
October	4.46	37.76	1.28	19.36	2.45	18.40	full.	1.15	21.22
November	3.07	40.83	.88	20.24	2.19	20.59	full.	1.73	22.95
1876-7.									
December	3.88	3.88	.73	.73	3.15	3.15	full.	.72	.72
January	2.54	6.42	.47	1.20	2.07	5.22	full.	.74	1.46
February	.62	7.04	.33	1.53	1.14	6.36	.85	.78	2.24
March	5.16	12.20	.90	2.43	3.41	9.77	full.	3.92	6.16
April	2.35	14.55	.99	3.42	1.62	11.39	.26	4.64	10.80
May	1.26	15.81	1.91	5.33	.84	12.23	1.75	1.91	12.71
June	4.92	20.73	3.36	8.69	.77	13.00	.96	.88	13.59
July	6.01	26.74	4.32	13.01	1.00	14.00	.27	1.07	14.66
August	3.32	30.06	3.11	16.12	.96	14.96	1.02	.97	15.63
September	1.38	31.44	1.72	17.84	.74	15 70	2.10	.76	16.39
October	6.18	37.62	1.46	19.30	2.62	18.32	full.	1.34	17.73
November	5.14	42.76	1.05	20.35	4.09	22.41	full.	3.19	20.92

Observed and Computed Flow, Connecticut River—Continued.

MONTH.	Monthly rainfall = r.	Total rainfall = R.	Monthly evaporation = e.	Total evaporation = E.	Computed monthly flow = f.	Computed total flow = F.	Depletion of ground-water.	Observed monthly flow.	Observed total flow.
1877–8.									
December	1.44	44.20	.50	20.85	.94	23.35	full.	1.95	22.87
January	3.20	47.40	.53	21.38	2.67	26.02	full.	1.26	24.13
February	2.56	49.96	.51	21.89	2.05	28.07	full.	2.06	26.19
March	2.23	52.19	.63	22.52	1.60	29.67	full.	3.67	29.86
April	7.52	59.71	1.46	23.98	6.06	35.73	full.	5.21	35.07
May	2.64	62.35	2.16	26.14	1.22	36.95	.74	3.59	38.66
June	4.79	67.14	3.33	29.47	1.06	38.01	.34	1.51	40.17
July	3.29	70.43	3.59	33.06	.86	38.87	1.50	.87	41.04
August	4.23	74.66	3.30	36.36	.66	39.53	1.23	1.12	42.16
September	2.34	77.00	1.89	38.25	.77	40.30	1.55	.84	43.00
October	2.34	79.34	1.04	39.29	.78	41.08	1.03	.80	43.80
November	4.11	83.45	.96	40.25	2.12	43.20	full.	1.81	45.61

Summary by Seasons, Connecticut River.

	1874-5.			1876-7.			1877–8.		
	Rainfall.	Computed flow.	Observed flow.	Rainfall.	Computed flow.	Observed flow.	Rainfall.	Computed flow.	Observed flow.
Winter	8.17	6.54	2.62	7.04	6.36	2.24	7.20	5.66	5.27
Spring	8.96	5.43	12.89	8.77	5.87	10.47	12.39	8.88	12.47
Dec. to May	17.13	11.97	15.51	15.81	12.23	12.71	19.59	14.54	17.74
Summer	13.14	3.06	3.82	14.25	2.73	2.92	12.31	2.58	3.50
Autumn	10.56	5.56	3.62	12.70	7.45	5.29	8.79	3.67	3.45
Jan. to Nov.	23.70	8.62	7.44	26.95	10.18	8.21	21.10	6.25	6.95
Year	40.83	20.59	22.95	42.76	22.41	20.92	40.69	20.79	24.69

In the Connecticut, as in the Potomac series, there are some periods of six months in which a mere inspection shows the flow to be much too large in proportion to the rainfall shown by available records.

The following are examples from the Connecticut series:

1872–3	December to May	Rain, 18.08	Flow, 21.83
1873-4	" "	" 20.24	" 24.07
1875-6	" "	" 20.41	" 25.15

Such discrepancies cannot be reconciled, and are so clearly due either to some discrepancy in gauging or to insufficient rainfall data that we have thrown them out. Clearly they are unsafe guides to any knowledge of the real relation between the flow of the Connecticut and the rainfall upon its water-shed.

The other discrepancies above shown are generally explainable. Thus during the first half of 1874–5 and 1877–8 there were probably snow and ice carried over from the autumn before. Indeed, the autumn flow of 1877 shows that such was the case. In general, there are enough points of coincidence between computed and observed flows to at least strongly suggest that with data as good as we have for the Passaic and Sudbury the agreement would be equally good for the Connecticut, excepting for the fact that there is a much larger holding back of the flow in the form of snow and ice. The carrying over of winter flow into spring, and even June, on this stream is well illustrated by the daily-flow diagrams of the stream given in the appendix.

General Conclusions.

The result of our analysis, therefore, may be summarized as follows:

1. All streams are outlets for surplus waters not evaporated or drawn up to support vegetation.

2. Evaporation is mainly affected by the temperature of the atmosphere, and such temperature is the principal cause of variation in the total run-off of streams. Difference in the character of vegetation upon the water-shed will produce lesser differences in flow, which are scarcely appreciable for such a range of conditions as we have presented by the water-sheds under consideration.

3. The dry-weather flow of a stream is mainly affected by the flow from ground-water.

4. When rain is less than evaporation plus stream-flow, the deficiency is made up from stored ground-water, which may at times supply the equivalent of six inches of rain, but the larger the amount

thus supplied during dry seasons the larger the deficiency to be made good from subsequent rains; consequently, a larger dry-season flow does not mean a larger total run-off.

5. The distribution of flow has little to do with the total yield of a water-shed, and our analysis does not seem to warrant the common conclusion that such yield varies from 80 to 90 per cent. for steep, mountainous water-sheds to 45 or 50 per cent. for flat, cultivated lands and prairies. We do find a greater percentage of yield from colder water-sheds and for heavy rainfalls, and believe that it is due to the fact that the conditions of heavier rainfall and cooler air usually obtain in mountainous countries that this theory has gained credence.

For dry years, however, our theory of flow explains and agrees with the best engineering practice. Actual experience has resulted in hydraulic engineers adopting between 15 and 11 inches as the available total run-off of streams in this region in dry years. Let us take the driest years of our different streams and see what they teach:

Stream.	Year.	Rainfall.	Observed Flow.	Flow Computed by Yearly Formula.
Sudbury	1882-3	31.55	11.40	11.00
Croton	1879-80	37.61	14.78	16.09
Passaic	1879-80	37.98	16.97	16.15
Neshaminy	1891-2	44.25	18.20	19.41
Perkiomen	1886-7	45.59	20 37	20.52
Connecticut	1876-7	42.76	20.92	22.65
Potomac	1886-7	36 40	15.06	12.95

The differences here shown between the computed and observed flows are mainly due to draughts upon ground-water, causing an excess, or to depleted ground-water at beginning of year, causing a deficiency in observed flow. Our comparison of observed and computed flows by months shows this in detail. What we wish to impress upon the reader is that there is every reason to expect from the above that any of these streams would show as small, or a smaller, flow than the Sudbury with an equally light rainfall. Therefore, if the rainfall upon their water-sheds is likely to fall as low as 31.55, their minimum flow will be 11 inches or less. Our rainfall records show that such a low rainfall is likely to be reached at long intervals, and that consequently we may expect a minimum of 11 inches flow upon the

Sudbury, Croton and Passaic, of 9 inches on the Neshaminy, Perkiomen and Potomac and 13 inches upon the Connecticut water-shed, at least upon portions of their water-shed not larger than the Sudbury drainage area, or about 75 square miles. We are inclined to the opinion that these extremely light rainfalls are usually local, and therefore that larger water-sheds are rarely subject to a less annual rainfall than about 35 inches in the New England and Middle States, corresponding to a flow of 12 inches for the Perkiomen, Neshaminy and Potomac, 14 inches for the Passaic, Croton and Sudbury and 16 inches for the Connecticut.

Maximum and Minimum Flow.

Thus far we have not touched upon the question of the relative steadiness of flow of different streams. The monthly flow which we deduce by our formula will give a very good idea of the value of a stream for water-supply or water-power. In general, the larger the ground-flow the steadier the stream as to daily variation of flow. The diagrams of daily flow which we give in the appendix are also guides to the characteristics of the several streams. The next point of importance for industrial purposes is the maximum and minimum flow of the streams. We cannot do better than give for this purpose a collection of the observed maxima and minima expressed in cubic feet per second per square mile of water-shed. Such a table will enable one to judge how great flood-flows must be provided for, and how low the flow is likely to fall for a few of the driest days of a great drought. It will be useful for comparison as we take up the several streams of the State in detail.

TABLE No. 42.

Greatest and Least Flow of Streams.

RIVER.	PLACE.	Drainage area, square miles.	EXTREMES OF FLOW.		Maximum cubic feet per second per square mile.	Minimum cubic feet per second per square mile.	AUTHORITY AND REMARKS.
			Maximum cubic feet per second.	Minimum cubic feet per second.			
	NEW ENGLAND.						
Merrimack	Lowell	4,085	81,000	1,275	19.83	0.31	Lakes and artificial reservoirs. Wooded.
Merrimack	Lawrence	4,599	96,000	1,400	20.87	0.31	Lakes and artificial reservoirs. Wooded.
Concord	Lowell	361	4,449	59.84	12.32	0.17	C. Herschel. Stream sluggish and swampy. Few woods. Hilly and rolling. Some reservoirs.
Sudbury	Framingham	78	3,228	2.80	41.38	0.036	A. Fteley. Hilly and swampy. One-sixth to one-eighth wooded.
Charles	Newton Upper Falls	215	....	44	....	0.20	J. P. Kirkwood. Hilly and rolling.
Hale's Brook, Mass.	....	24	....	3.24	....	0.135	J. P. Frizell.
Connecticut	Hartford	10,234	207,443	5,219	20.27	0.510	T. G. Ellis. Numerous lakes and artificial reservoirs. Wooded. Mountainous in parts.
Connecticut	Dartmouth	3,287	....	1,006	....	0.306	C. Herschel. Numerous lakes and artificial reservoirs. Wooded. Mountainous in parts.
Housatonic	....	790	....	130	....	0.165	H. Loomis. Report New York Committee Public Works, 1879.
	NEW YORK.						
Croton	....	338.82	25,367	50.80	74.87	0.150	J. J. R. Croes and G. W. Howell.
Croton (west branch)	....	20.37	1,109	0.407	54.44	0.020	J. J. R. Croes. Very broken and undulatory. Hills steep and rocky. Largely wooded. Little cultivated.
	NEW JERSEY.						
Ramapo	Pompton	159.5	10,540	22.5	66.1	0.14	Minimum, October, 1892
Wanaque	Pompton	101.0	4,943	....	48.9	....	Observed maximum. Actual probably as high as Ramapo.
Pequannock	Pompton	84.7	4,460	....	52.7	....	
Pequannock	Macopin Int'ke	62.6	....	8.0	....	0.13	Clemens Herschel, Oct. 1892.
Rockaway	Dover	52.2	2,250	....	43.0	....	
Rockaway	Boonton	118.9	4,800	....	40.7	....	
Passaic	Chatham	99 8	....	....	....	0.14	From run of mills.
Passaic	Paterson	796.9	....	195	....	0.24	Croes & Howell, Oct., 1875.
Passaic	Paterson	796.9	....	150	....	0.19	L. B. Ward, September, 1883. This flow is occasionally not exceeded for more than two weeks.—C. C. V.
Passaic	Little Falls	772.9	19,105	....	24.2	....	
Passaic	Dundee	822.7	18,265	....	22.2	....	These last two maxima September, 1882.
Hackensack	....	84.0	....	....	....	0.33	C. D. Ward.
Hackensack	New Milford	114.8	....	21.7	....	0.19	C. B. Brush.
Raritan	Bound Brook	879.0	52,000	180	59.3	0.20	Minimum by Ashbel Welch.
Raritan	Bound Brook	879.0	....	122	....	0.14	Oct. 13th-19th, 1892.—C. C. V.
Delaware	Stockton	6,790.0	254,643	1,179	37.5	0.17	Minimum, September, 1881.
Musconetcong	Finesville	155.8	1,960	....	12.8	....	

Greatest and Least Flow of Streams—Continued.

RIVER.	PLACE.	Drainage area, square miles.	EXTREMES OF FLOW.		Maximum cubic feet per second per square mile.	Minimum cubic feet per second per square mile	AUTHORITY AND REMARKS.
			Maximum cubic feet per second.	Minimum cubic feet per second.			
Musconetcong..	Saxton Falls....	68.0	1,080	....	15.9	....	
Paulinskill.......	Hainesburgh....	174.8	4,126	29.0	23.0	0.170	Least in 1890.
Paulinskill.......	Paulina	126.0	....	17.0	....	0.130	From run of mill in 1881.
Paulinskill.......	Stillwater.........	....	....	16.5	....	....	From run of mill in 1881.
Paulinskill.......	Balesville.........	50.0	....	6.3	....	0.126	From run of mill in 1881.
Jacksonburgh branch..........	Jacksonburgh..	7.8	....	1.9	....	0.250	From run of mill in 1881.
Swartsw'd lake outlet............	Swartsw'd lake	16.0	1,070	....	65.8	....	
Pequest............	Belvidere	158.0	1,996	....	12.5	....	
Pequest.	Townsbury	83.4	800	14.0	9.6	0.170	Minimum from run of mill.
Pequest............	Tranquility	34.8	650	....	18.7	....	
Pequest............	Huntsville	31.4	605	....	19.3	....	
Pequest............	Allamuchy p'd.	1.7	40	....	23.5	....	
Pequest............	Hunt's Pond....	1.7	43	....	25.3	....	
Great Egg Harbor.	May's Landing	215.8	4,756	59.0	22.0	0.270	
Maurice River.	Millville	218.0	....	85.0	....	0.390	Minimum probably not greater than the Great Egg Harbor without storage.
	PENNSYLVANIA.						
Tohickon.........	Point Pleasant.	102.2	5,546	0.21	54.3	0.001	Annual Reports of Chief Engineer of Philadelphia Water Department.
Neshaminy	Forks...............	139.3	5,767	1.26	41.4	0.009	
Perkiomen	Frederick.........	152.0	5,305	7.56	34.9	0.05	
Schuylkill	Philadelphia....	1,800	....	307 to 378	....	0.17 to 0.21	E F. Smith and H. P. M. Birkinbine. Hilly and rolling. No lakes. Some reservoirs.
Ohio.................	Pittsburgh........	19,900	....	2,271	....	0.114	J. H. Harlow. Hilly and mountainous. No lakes. Wooded.
	SOUTHERN.						
Potomac...........	Cumberland.....	920	17,900	25	19.46	0.022	W. R. Hutton and Patterson. Narrow valleys. Steep slopes. Wooded. No lakes.
Potomac	Dam No. 5........	4,640+	92,772	363	22.15	0.0783	Quoted by W. R. Hutton. Narrow valleys. Steep slopes. Wooded. No lakes.
Potomac	Great Falls.......	11,476	175,000	1,063	15.25	0.093	W. R. Hutton. Country more open. No lakes.
Rock Creek	Hoyle's Mill.....	64.40	....	7.50	....	0.114	Quoted by W. R. Hutton.
Kanawha	Cha'ston Pool...	8,900	120,000	1,100	13.49	0.123	Gill, Scott and Hutton. Mountainous. Steep. No lakes. Wooded.
Greeenbrier.....	Mouth of Howard's Creek...	870	....	97	....	0.120	McNeill. Mountainous. Steep. No lakes. Wooded.
Shenandoah	Near Port Republic	770	....	128	....	0.167	James Herron. Hilly. Limestone. No lakes. Many springs.
James...............	Richmond	6,800	....	1,300	....	0.191	E D. Whitcomb and W. E. Cutshaw. Mountainous in upper part. No lakes. Wooded.
Neuse	Near Raleigh...	1,000	....	....	....	0.193	W. C. Kerr. Low water. Open. Clay and loam. No lakes. Few extensive woods.

The maximum flow of a stream is affected by the steepness of slopes of drainage area and the length and distribution of the branches. A long, narrow drainage basin, with short branches well distributed along the main stream, like the Musconetcong, will give a much smaller flood-flow than one nearly round with several large branches focusing into one center, like the Raritan. Again, such a watershed as the latter may have great flats bordering the streams over which flood-waters spread and are delivered gradually to the lower stream, like the Passaic. These facts make it impossible to classify the streams according to volume of flood-flow. The least flows, however, are affected almost entirely by the ground and surface-storage facilities of the drainage areas. We may compare these flows intelligently. Let us separate the above streams into classes, according to size of drainage area.

TABLE No. 43.

Drainage Areas of From 0 to 200 Square Miles.

Stream.	Drainage Area. Square Miles.	Minimum Flow. Cubic Feet per Second per Square Mile.
Sudbury	78	.036
Hale's Brook	24	.135
Croton, West Branch	20	.020
Ramapo	160	.140
Pequannock	63	.130
Paulinskill	126	.130
Pequest	83	.170
Tohickon	102	.001
Neshaminy	139	.009
Perkiomen	152	.050
Rock Creek	64	.114
Hackensack	115	.190

Drainage Area, 200 to 2,000 Square Miles.

Stream.	Drainage Area. Square Miles.	Minimum Flow. Cubic Feet per Second per Square Mile.
Concord	361	.170
Charles	215	.200
Housatonic	790	.165
Croton	339	.150
Passaic	797	.170
Schuylkill	1,800	.170
Raritan	879	.140

Stream.	Drainage Area. Square Miles.	Minimum Flow. Cubic Feet per Second per Square Mile.
Potomac	920	.022
Greenbrier	870	.120
Shenandoah	770	.167
Neuse	1,000	.193
Great Egg Harbor	216	.270

Drainage Area over 2,000 Square Miles.

Stream.	Drainage Area. Square Miles.	Minimum Flow. Cubic Feet per Second per Square Mile.
Merrimack	4,599	.310
Connecticut	10,234	.306
Delaware	6,790	.170
Ohio	19,900	.114
Potomac	4,640	.078
Kanawha	8,900	.123
James	6,800	.191

Of the first group of smaller streams it should be noted that on streams of this size the absolute minimum may be zero. The flow may be easily reduced at times to nothing by the temporary holding back of the flow in some mill-pond or reservoir, and always, from such causes, it is difficult to determine the natural minimum by observation. We believe that this is partly the reason for the wider variation of minimum flow noticeable for the smaller streams, although of course small drainage areas will also differ more in the yield from ground-water than larger ones. The Sudbury minimum flow would seem to be abnormally small for a stream of its class. It is noticeable that the Croton west branch is also low in its minimum. The first seven streams, together with Rock creek, belong to a class of hilly or mountainous drainage areas of a type generally resembling our own Kittatinny valley and Highland regions. They show a minimum ranging from .020 to .170, with a strong probability that the natural minimum ranges between .10 and .15 for such streams.

The Tohickon and Neshaminy are representative of the red sandstone region, the streams of which are of known low dry-season flow, and it is probable that .009 fairly represents the minimum of streams of about 100 square miles water-shed of this type, while smaller streams of high channel slope and shallow valleys sometimes entirely dry up.

The Perkiomen drainage area is of a mixed character, lying partly upon the gneissic hills and partly upon the red sandstone plain.

The Hackensack represents the red sandstone plain north of the terminal moraine. The glaciated portion covered with sand, gravel and boulder earth, and incidentally more forested.

The next group of streams show less variation in minimum flow, the drainage being large enough to make them less susceptible to artificial interference. The first seven of these belong to the same class with our Highland and Kittatinny valley drainage areas, and range between .14 and .17.

The Great Egg Harbor is a type of southern New Jersey streams with flat, sandy water-sheds. The Raritan is a mixed type, having 275 square miles of Highland water-shed, 100 square miles of sandy plain and the remaining 504 square miles being red sandstone, with but one small lake upon the whole.

Allowing .27 for the sandy and .17 for the highland portion, we have for the red sandstone portion of the Raritan drainage .11. The results of our other gaugings show this to be about the correct minimum. The smaller water-sheds of this red sandstone region are quite variable in minimum yield.

Of the southern streams, the yield of the Upper Potomac is remarkably low for a water-shed of the size. The Shenandoah and Neuse seem to agree with the first seven streams, while the Greenbrier is also below. It is probable that the normal minimum is lower than for the same class of drainage areas further north, ranging perhaps from .12 to .17.

The third class, including only the larger streams, seem to show a decrease of minimum flow generally corresponding to increase of mean temperature. The Delaware probably represents a safe minimum for this class for New England and the Atlantic slope of the Middle States, as the value given is more likely to be the true minimum than that of either the Merrimac or Connecticut. The latter, especially, probably at times approaches a minimum of .25. This is believed to be the lowest point reached by the Delaware during the past 60 years.

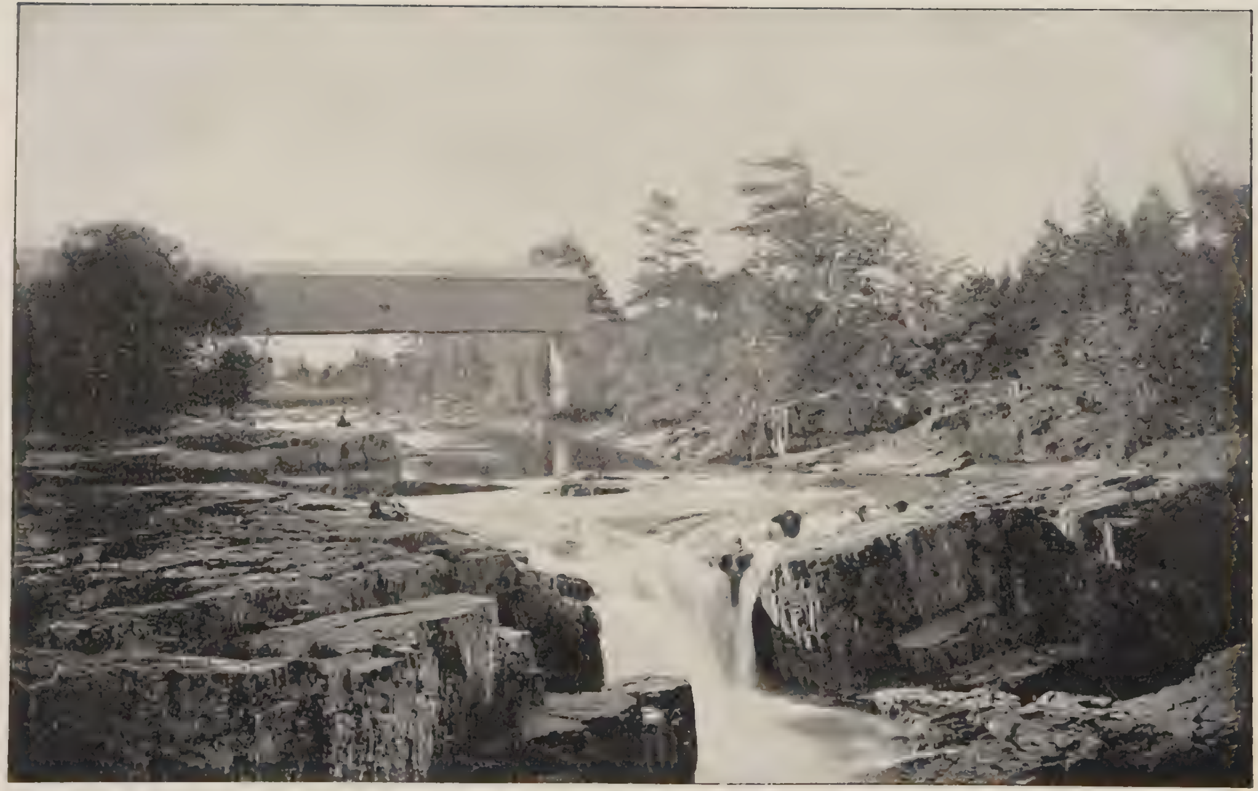
Because of lighter rainfall and greater evaporation, the Ohio shows a lower minimum and the Potomac still lower. It may be fairly assumed that at times the Kanawha and James will approach the Potomac minimum. We cannot follow the above figures safely without taking into account the relative weight to be attached to the several values given, and this we have attempted to do in our present discussion, as well as throughout this report.

APPLICATION OF FORMULA TO NEW JERSEY STREAMS.

Thus far we have based our work upon gaugings extending over long periods and of known fair accuracy. We know of no more prolific cause of error in discussion of stream-flow, its variations and the causes thereof, than reasoning too far from meagre data. We have consequently included but one of our New Jersey series of gaugings in our general discussion, viz., the seventeen-year series on the Passaic, one which will compare favorably in length and character with any of those used. Nevertheless, we shall now find our shorter series most useful in corroborating our conclusions, and indispensable in fixing the minor characteristics of the several streams. We have deemed it best to introduce these gaugings at the beginning of the discussion of the stream to which they belong, so that the reader is here requested to refer to them there should he wish to verify our general statements.

SELECTION OF DRIEST PERIOD.

In our chapter on rainfall, we gave two typical dry periods from the New York and two from the Philadelphia record. We are now prepared to examine these and determine which of them presents the most severe drought in its effects upon stream-flow and vegetation. The best way to do this is to compute by our formula the flow of the Passaic by months for each of the two driest periods, and then compare the results. A test for one stream will answer for all.



LITTLE FALLS AT A LOW STAGE OF THE PASSAIC.

TABLE No. 44.

Estimate of Passaic Flow for Typical Dry Periods.

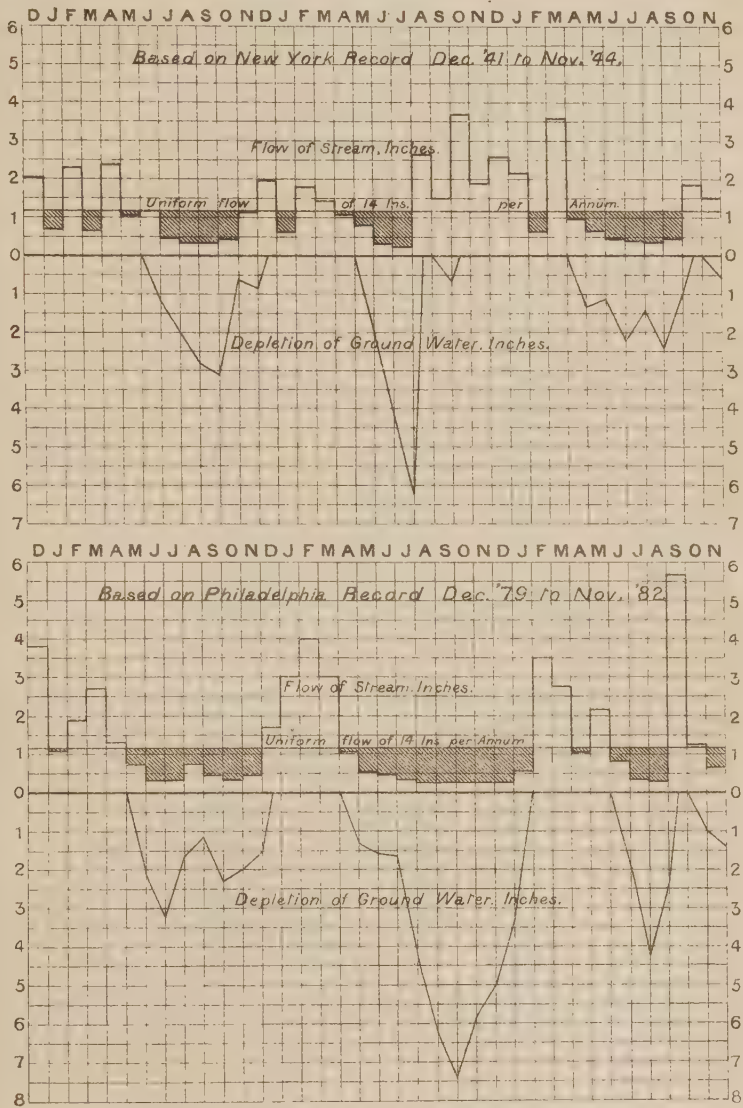
MONTH.	NEW YORK RECORD. Dec., 1841, to Nov., 1844.				PHILADELPHIA RECORD. Dec., 1879, to Nov., 1882.			
	Rainfall.	Evaporation.	Flow.	Depletion of ground-water.	Rainfall.	Evaporation.	Flow.	Depletion of ground-water.
December	2.70	.69	2.01	....	4.69	.89	3.80	....
January	1.07	.38	.69	....	1.51	.42	1.09	....
February	2.85	.58	2.27	....	2.43	.54	1.89	....
March	1.25	.61	.64	....	3.53	.83	2.70	....
April	3.60	1.23	2.37	....	2.43	1.11	1.32	....
May	3.60	2.59	1.01	....	.54	1.98	.72	2.16
June	3.30	3.32	1.16	1.18	1.67	2.92	.31	3.72
July	3.80	4.14	.48	2.00	7.74	5.32	.32	1.62
August	2.81	3.32	.33	2.84	5.09	3.89	.72	1.14
September	2.10	2.05	.32	3.11	1.10	1.85	.43	2.32
October	4.30	1.39	.43	.63	1.74	1.09	.34	2.01
November	1.80	.84	1.12	.79	1.75	.84	.43	1.53
Year	33.18	21.14	12.83	....	34.22	21.68	14.07	....
December	3.50	.77	1.94	....	4.05	.83	1.69	....
January	1.00	.37	.63	....	3.66	.64	3.02	....
February	2.31	.53	1.78	....	4.76	.78	3.98	....
March	2.13	.69	1.44	....	3.83	.86	2.97	....
April	2.14	1.08	1.06	....	.61	.93	1.05	1.37
May	1.00	2.07	.81	1.88	2.71	2.41	.52	1.59
June	.76	2.69	.31	4.12	3.87	3.47	.46	1.65
July	1.64	3.49	.24	6.21	.96	3.29	.32	4.30
August	15.26	6.43	2.62	....	1.18	2.92	.25	6.29
September	3.06	2.24	1.47	.65	.94	1.82	.25	7.42
October	5.91	1.59	3.67	....	3.04	1.24	.25	5.87
November	2.82	.94	1.88	....	2.02	.86	.25	4.96
Year	41.53	22.89	17.85	....	31.63	20.05	15.01	....

Estimate of Passaic Flow for Typical Dry Periods—Continued.

MONTH.	NEW YORK RECORD. Dec., 1841, to Nov., 1844.				PHILADELPHIA RECORD. Dec., 1879, to Nov., 1882.			
	Rain.	Evaporation.	Flow.	Depletion of ground-water.	Rain.	Evaporation.	Flow.	Depletion of ground-water.
December	3.34	.75	2.59	....	2.63	.68	.27	3.28
January	2.66	.54	2.12	....	4.57	.73	.56	....
February	1.03	.40	.63	....	4.22	.72	3.50	....
March	4.50	.93	3.57	....	3.57	.84	2.73	....
April	.55	.92	.95	1.32	2.12	1.08	1.04	....
May	3.41	2.55	.64	1.10	5.06	2.88	2.18	....
June	2.37	3.09	.43	2.25	1.90	2.98	.81	1.89
July	6.00	4.80	.40	1.45	1.37	3.41	.32	4.25
August	2.73	3.30	.38	2.40	6.40	4.22	.30	2.37
September	4 50	2.53	.46	.89	12.09	4.05	5 67	....
October	4.08	1.37	1.82	....	1.32	1.04	1.26	.98
November	1.73	.83	1.50	.60	.99	.76	.65	1.40
Year	36.90	22.01	15.49	....	46.24	23.39	19.29	....

The smallest yearly flow here shown is from December, 1841 to November, 1842, in the Philadelphia series. Other tests will show, however, why this is not the most severe drought, either measured by the test of draught upon artificial reservoirs for water-supply, by the run of the stream without storage or by the severity of the drought upon vegetation. The accompanying diagrams will make this clear. The upper part of each shows the stream-flow accompanied by a horizontal line, which represents a steady flow equal to 14 inches per annum, the amount which we adopt as a preliminary maximum available with storage reservoirs. The shaded parts below this line represent the amounts which would have to be drawn from storage reservoirs in each case to make up the flow to 1.17 inches upon the water-shed per month, or 14 inches per annum. Table No. 45 shows what would be the draught upon such storage reservoirs for each period.

Plate 5.



COMPUTED FLOW OF PASSAIC FOR
EXTREME DRY PERIODS.

JULIUS BIEN & CO. N.Y. J.R. Bruce Del.

TABLE No. 45.

Draught on Storage Reservoirs to Furnish Uniform Supply of 14 Inches Annually.

MONTH.	NEW YORK SERIES. Dec., 1841, to Nov., 1844.				PHILADELPHIA SERIES. Dec., 1879, to Nov., 1882.			
	Natural flow.	Excess.	Deficiency.	Total depletion.	Natural flow.	Excess.	Deficiency.	Total depletion.
December	2.01	.84			3.80	2.63		
January	.69		.48	.48	1.09		.08	.08
February	2.27	1.10			1.89	.72		
March	.64		.53	.53	2.70	1.53		
April	2.37	1.20			1.32	.15		
May	1.01		.16	.16	.72		.45	.45
June	1.16		.01	.17	.31		.86	1.31
July	.48		.69	.86	.32		.85	2.16
August	.33		.84	1.70	.72		.45	2.61
September	.32		.85	2.55	.43		.74	3.35
October	.43		.74	3.29	.34		.83	4.18
November	1.12		.05	3.34	.43		.74	4.92
Year	12.83				14.07			
December	1.94	.77		2.57	1.69	.52		4.40
January	.63		.54	3.11	3.02	1.85		2.55
February	1.78	.61		2.50	3.98	2.81		
March	1.44	.27		2.23	2.97	1.80		
April	1.06		.11	2.34	1.05		.12	.12
May	.81		.36	2.70	.52		.65	.77
June	.31		.86	3.56	.46		.71	1.48
July	.24		.83	4.39	.32		.85	2.33
August	2.62	1.45		2.94	.25		.92	3.25
September	1.47	.30		2.64	.25		.92	4.17
October	3.67	2.50		.14	.25		.92	5.09
November	1.88	.71			.25		.92	6.01
Year	17.85				15.01			

Draught on Storage Reservoirs to Furnish Uniform Supply of 14 Inches Annually—Continued.

MONTH.	NEW YORK SERIES. Dec., 1841, to Nov., 1844.				PHILADELPHIA SERIES. Dec., 1879, to Nov., 1882.			
	Natural flow.	Excess.	Deficiency.	Total depletion.	Natural flow.	Excess.	Deficiency.	Total depletion.
December	2.59	1.42	....	....	.27	....	.90	6.91
January	2.12	.95	....	....	.56	....	.61	7.52
February	.63	....	.54	.54	3.50	1.33	....	6.19
March	3.57	2.40	....	....	2.73	1.56	....	4.63
April	.95	....	.22	.22	1.04	....	.13	4.76
May	.64	....	.53	.75	2.18	1.01	....	3.75
June	.43	....	.74	1.49	.81	....	.36	4.11
July	.40	....	.77	2.26	.32	....	.85	4.96
August	.38	....	.79	3.05	.30	....	.87	6.83
September	.46	....	.71	3.76	5.67	4.50	....	2.33
October	1.82	.65	....	3.11	1.26	.09	....	2.26
November	1.50	.33	....	2.78	.65	....	.52	2.78
Year	15.49	....	....	....	19.29	....	....	....

In the above table, the column marked "Total depletion" shows the total amount of storage which would have to be drawn up to the end of a given month, measured in inches upon the water-shed, in order to supply continuously at the rate of 14 inches per annum. It will be noted that the longest period in which the reservoirs would be drawn down on the basis of the New York record of 1841 to 1844 is eighteen months, and that the greatest amount drawn from storage is 4.39 inches. On the basis of the Philadelphia series of 1879 to 1882, the draught from storage at the end of January, 1882, amounts to 7.52 inches. A brief examination shows that the reservoirs would not fill until March, 1883, so that we have here twenty-two consecutive months in which the reservoirs would be drawn down. It is apparent, therefore, that if we admit that the Passaic is subject to droughts as great as this, 14 inches per annum is the very highest amount which we can collect, and to do so we shall need seven and one-half inches of storage above any allowance which may be necessary for extra evaporation from the reservoir surface. The reader will note that during these years the rainfall upon the Passaic water-shed did not actually fall as low as that shown by this Phila-

delphia record, and that, consequently, the flow of the Passaic was larger than this computed flow. As I before remarked, however, we have no warrant for supposing that the rainfall will not, at some time, fall as low as this on the smaller water-sheds, at least.

It is made clear by the above table that the Philadelphia rainfall from December, 1879, to November, 1882, is the most trying one upon a system of artificial storage. Table No. 44 shows that it was also the most trying upon natural storage, the periods of depletion of ground-water being longer, and the greatest draught upon ground-water amounting to 7.42 inches, whereas the greatest of the New York record is 6.21 inches. The low state of ground-water from April, 1881, to December, 1881, for nine continuous months, exhibits the severity of the famous drought of 1881, which was so severe as to kill large numbers of forest trees. The condition of ground-water is exhibited by the lowest line of Plate V.

In our future computations, we shall adopt the above dry season of the Philadelphia record for our typical dry period. We have already given in the chapter on rainfall the average rainfall for each section in the State. Applying our monthly formula for the Passaic, Croton and Sudbury, we shall be able to compute the evaporation on the Passaic for an average and extreme dry period. By taking the difference in mean temperature between the Passaic and each of the other sections of the State, and applying a correction of five per cent. for each one degree of increase and decrease over the mean annual temperature of the Passaic, Croton and Sudbury, we shall have the evaporation for the average and extreme dry periods for the several sections of the State. We obtained the following series of mean annual temperatures from the Climatology of New Jersey, and opposite each we have set the proper correction to be applied to the evaporation formulæ for the Passaic, Croton and Sudbury:

MEAN ANNUAL TEMPERATURE.

		Correction to Evaporation.
Upper Delaware Valley	47.4 degrees	— 11.5 per cent.
Highlands and Kittatinny Valley	47.4 "	— 11.5 "
Central Delaware Valley	50.6 "	+ 5 "
Red Sandstone Plain	50.6 "	+ 5 "
Southern Divide	52.6 "	+ 15 "
Seacoast	52.1 "	+ 12 "
Lower Delaware	52.6 "	+ 15 "

			Correction to Evaporation.	
Delaware above Trenton	47.4	degrees	— 11.5	per cent.
Raritan	50.6	"	+ 5	"
Passaic	49.7	"	0	"
Coast Streams	52.5	"	+ 14	"
Branches of Delaware below Camden	52.5	"	+ 14	"
Branches of Delaware, Camden to Trenton	52.5	"	+ 14	"

Applying the above corrections, we obtain the following monthly evaporation for the several sections of the State:

TABLE No. 46.

Rainfall and Evaporation for Average, Ordinary Dry and Driest Periods.

(a) UPPER DELAWARE VALLEY, HIGHLANDS AND KITTATINNY VALLEY.

MONTH.	AVERAGE.		ORDINARY DRY.		DRIEST.	
	Rainfall.	Evaporation.	Rainfall.	Evaporation.	Rainfall.	Evaporation.
December	3.57	.60	3.86	.79	4.05	.74
January	3.48	.55	3.94	.58	3.66	.57
February	3.31	·56	1.64	.41	4.76	.69
March	3.57	.74	2.89	.68	3.83	.76
April	3.48	1.09	2.55	.99	.61	.88
May	3.88	2.35	3.29	2.24	2.71	2.13
June	3.88	3.07	3.66	3.02	3.87	3.07
July	4.05	3.73	4.35	3.80	.96	2.91
August	4.42	3.29	3.83	3.17	1.18	2.58
September	3.57	2.07	.96	1.61	.94	1.61
October	3.31	1.13	2.04	.99	3.04	1.10
November	3.57	.90	2.19	.78	2.02	.76
Year	44.09	20.08	35.20	19.06	31.63	17.75
December	....	....	....	....	2.63	.60
January	....	....	....	....	4.57	.65
February	....	....	....	....	4.22	.64
March	....	....	....	....	3.57	.74
April	....	....	....	....	2.12	.96
May	....	....	....	....	5.06	2.55
June	....	....	....	....	1.90	2.64
July	....	....	....	....	1.37	3.02
August	....	....	....	....	6.40	3.73
September	....	....	....	....	12.09	3.58
October	....	....	....	....	1.32	.92
November	....	....	....	....	.99	.67
Year	....	....	....	....	46.24	20.70

Rainfall and Evaporation for Average, Ordinary Dry and Driest Periods—Continued.

(b) CENTRAL DELAWARE VALLEY, RED SANDSTONE PLAIN, RARITAN WATER-SHED.

MONTH.	AVERAGE.		ORDINARY DRY.		DRIEST.	
	Rainfall.	Evaporation.	Rainfall.	Evaporation.	Rainfall.	Evaporation.
December	3.72	.83	4.04	.86	4.05	.87
January	3.63	.66	4.12	.71	3.66	.67
February	3.45	.67	1.71	.49	4.76	.82
March	3.72	.89	3.02	.82	3.83	.90
April	3.63	1.29	2.67	1.20	.61	.98
May	4.04	2.81	3.44	2.69	2.71	2.53
June	4.04	3.70	3.82	3.62	3.87	3.64
July	4 23	4.48	4.55	4.58	.96	3.45
August	4.59	3.96	4.00	3.80	1.18	3.06
September	3.72	2.49	1.01	1.92	.94	1.91
October	3.45	1.36	2.14	1.19	3.04	1.30
November	3.72	1.08	2.28	.94	2.02	.90
Year	45.94	24.22	36.80	22.82	31.63	21.03

December					2.63	.71
January					4.57	.77
February					4.22	.76
March					3.57	.88
April					2.12	1 13
May					5.06	3.02
June					1.90	3.13
July					1.37	3.58
August					6.40	4.43
September					12.09	4.25
October					1 32	1.09
November					.99	.80
Year					46.24	24.55

Rainfall and Evaporation for Average, Ordinary Dry and Driest Periods—Continued.

(c) DELAWARE WATER-SHED, ABOVE TRENTON.

MONTH.	AVERAGE.		ORDINARY DRY.		DRIEST.	
	Rainfall.	Evaporation.	Rainfall.	Evaporation.	Rainfall.	Evaporation.
December	3.67	.70	3.95	.72	4.05	.73
January	3.57	.56	4.04	.59	3.66	.57
February	3.40	.57	1.67	.42	4.76	.67
March	3.67	.75	2.95	.67	3.83	.76
April	3.57	1.09	2.60	1.00	.61	.82
May	3.99	2.45	3.36	2.25	2.71	2.13
June	3.99	3.10	3.73	3.03	3.87	3.17
July	4.17	3.76	4.47	3.84	.96	2.91
August	4.52	3.32	3 93	3.18	1.18	2.58
September	3.67	2.18	.99	1.62	.94	1.61
October	3.40	1.14	2.09	1.00	3.04	1.10
November	3.67	.92	2.22	.78	2.02	.76
Year	45.29	20.54	36.00	19.10	31.63	17.81

December					2.63	.60
January					4.57	.65
February					4.22	.64
March					3.57	.74
April					2.12	.96
May					5.06	2.55
June					1.90	2.64
July					1.37	3.02
August					6.40	3.73
September					12.09	3.58
October					1.32	.92
November					.99	.67
Year					46.24	20.70

Rainfall and Evaporation for Average, Ordinary Dry and Driest Periods—Continued.

(d) PASSAIC WATER-SHED.

MONTH.	AVERAGE.		ORDINARY DRY.		DRIEST.	
	Rainfall.	Evaporation.	Rainfall.	Evaporation.	Rainfall.	Evaporation.
December	3.65	.78	3.95	.81	4.05	.83
January	3.55	.63	4.04	.67	3.66	.64
February	3.38	.64	1.67	.47	4.76	.78
March	3.64	.84	2.95	.78	3.83	.86
April	3.55	1.00	2.60	1.13	.61	.93
May	3.96	2.67	3.36	2.54	2.71	2.41
June	3.96	3.49	3.73	3.43	3.87	3.47
July	4.14	4.24	4.47	4.34	.96	3.29
August	4.50	3.74	3.93	3.60	1.18	2.92
September	3.64	2.36	.99	1.83	.94	1.82
October	3.38	1.29	2.09	1.13	3.04	1.24
November	3.65	1.02	2.22	.88	2.02	.86
Year	45.00	22.70	36.00	21.61	31.63	20.05

December					2.63	.68
January					4.57	.73
February					4.22	.72
March					3.57	.84
April					2.12	1.08
May					5.06	2.88
June					1.90	2.98
July					1.37	3.41
August					6 40	4.22
September					12.09	4.05
October					1.32	1.04
November					.99	.76
Year					46.24	23.39

Rainfall and Evaporation for Average, Ordinary Dry and Driest Periods—Continued.

(e) BRANCHES OF DELAWARE—TRENTON TO CAMDEN.

MONTH.	AVERAGE.		ORDINARY DRY.		DRIEST.	
	Rainfall.	Evaporation.	Rainfall.	Evaporation.	Rainfall.	Evaporation.
December	3.82	.91	4.13	.94	4.05	.95
January	3.73	.73	4.21	.79	3.66	.73
February	3.55	.75	1.75	.54	4.76	.89
March	3.82	.98	3.08	.90	3.83	.98
April	3.73	1.41	2.73	1.30	.61	1.06
May	4.16	3.08	3.52	2.93	2.71	2.75
June	4.16	4.04	3.90	3.96	3.87	3.95
July	4.35	4.91	4.64	5.01	.96	3.75
August	4.71	4.33	4.09	4.15	1.18	3.33
September	3.82	2.73	1.03	2.10	.94	2.07
October	3.55	1.50	2.18	1.30	3.04	1.41
November	3.82	1.19	2.34	1.03	2.02	.97
Year	47.22	26.56	37.60	24.95	31.63	22.85

December					2.63	.78
January					4.57	.83
February					4.22	.82
March					3.57	.96
April					2.12	1.23
May					5.06	3.28
June					1.90	3.40
July					1.37	3.89
August					6.40	4.81
September					12.09	4.62
October					1.32	1.19
November					.99	.87
Year					46.24	26.68

Rainfall and Evaporation for Average, Ordinary Dry and Driest Periods—Continued.

(f) BRANCHES OF DELAWARE—CAMDEN TO BRIDGETON.

MONTH.	AVERAGE.		ORDINARY DRY.		DRIEST.	
	Rainfall.	Evaporation.	Rainfall.	Evaporation.	Rainfall.	Evaporation.
December	3.72	.90	4.04	.93	4.05	.95
January	3.62	.72	4.12	.77	3.66	.73
February	3.44	.73	1.71	.54	4.76	.89
March	3.72	.97	3.02	.89	3.83	.98
April	3.62	1.40	2.67	1.30	.61	1.06
May	4.04	3.05	3.44	2.92	2.71	2.75
June	4.04	4.00	3.82	3.45	3.87	3.96
July	4.22	4.86	4.55	4.97	.96	3.75
August	4.58	4.29	4.00	4.13	1.18	3.33
September	3.72	2.70	1.01	2.10	.94	2.07
October	3.44	1.47	2.14	1.56	3.04	1.41
November	3.72	1.18	2.28	1.01	2.02	.97
Year	45.88	26.27	36.80	24.57	31.63	22.85
December					2.63	.78
January					4.57	.83
February					4.22	.82
March					3.57	.96
April					2.12	1.23
May					5.06	3.28
June					1.90	3.40
July					1.37	3.89
August					6.40	4.81
September					12.09	4.62
October					1.32	1.19
November					.99	.87
Year					46.24	26.68

Rainfall and Evaporation for Average, Ordinary Dry and Driest Periods—Continued.

(g) ATLANTIC COAST STREAMS OF SOUTHERN NEW JERSEY.

MONTH.	AVERAGE.		ORDINARY DRY.		DRIEST.	
	Rainfall.	Evaporation.	Rainfall.	Evaporation.	Rainfall.	Evaporation.
December	3.97	.97	4.29	.98	4.05	.95
January	3.88	.75	4.38	.78	3.66	.73
February	3.69	.76	1.82	.55	4.76	.89
March	3.97	1.01	3.21	.91	3.83	.98
April	3.88	1.44	2.83	1.31	.61	1.06
May	4.32	3.11	3.65	2.96	2.71	2.75
June	4.32	4.33	4.07	4.01	3.87	3.96
July	4.53	4.98	4.84	5.07	.96	3.75
August	4.91	4.39	4.26	4.19	1.18	3.33
September	3.97	2.76	1.16	2.12	.94	2.07
October	3.69	1.51	2.26	1.31	3.04	1.41
November	3.97	1.21	2.43	1.03	2.02	.97
Year	49.10	27.22	39.20	25.22	31.63	22.85

December	....	....	....	....	2.63	.78
January	....	....	....	....	4.57	.83
February	....	....	....	....	4.22	.82
March	....	....	....	....	3.57	.96
April	....	....	....	....	2.12	1.23
May	....	....	....	....	5.06	3.28
June	....	....	....	....	1.90	3.40
July	....	....	....	....	1.37	3.89
August	....	....	....	....	6.40	4.81
September	....	....	....	....	12.09	4.62
October	....	....	....	....	1.32	1.19
November	....	....	....	....	.99	.87
Year	....	....	....	....	46.24	26.68

This gives us the following net amounts of rain left to flow off in the streams for the various sections of the State:

Net Inches of Rain in Excess of Evaporation.

	Average Year.	Ordinary Dry Year.	Driest Year.
Upper Delaware Valley, Highlands and Kittatinny Valley	24.01	16.14	13.88
Central Delaware Valley, Red Sandstone Plain, Raritan Water-Shed	21.72	13.98	10.60
Delaware above Trenton	24.75	16.90	13.82
Passaic Water-Shed	22.30	14.39	11.58
Branches of Delaware—Trenton to Camden	20.66	12.65	8.78
Branches of Delaware—Camden to Bridgeton	19.61	12.01	8.78
Atlantic Coast Streams of Southern New Jersey	21.88	13.98	8.78

The actual amount of water run off in the driest year will, of course, be augmented by draught upon ground-storage. The assumption that all parts of the State will be subject to equally severe droughts tells heavily against the driest-year flow of southern New Jersey, where the average rainfall is higher. We should like to be convinced that such severe droughts are not to be looked for there, but we find nothing in the climatology of New Jersey, or in the records of rainfall which we have studied, to warrant such a conclusion.

The above sections embrace all classes of streams within the borders of the State, and we have here all necessary data, excepting the curves of ground-flow, for the computation of the stream-flow of the State.

Before proceeding to determine these curves, it may be well, however, to see what our New Jersey gaugings indicate as to the accuracy of our formulæ for evaporation. Very considerable discrepancies may be expected in such short series as these, still we may draw some valuable inferences.

TABLE No. 47.

Comparison of Kittatinny Valley and Highland Gaugings.

PAULINSKILL.

Period.	Rain.	Observed Evaporation.	Computed Evaporation for Passaic.	Difference. Per cent.
Year 1890-1891	46.48	22.20	22.94	—3
December to May, 1891	22.68	7.24	6.92	+5
June to November, 1890	23.80	14.96	16.06	—7

PEQUEST.				
June, 1890, to May 1891	46.32	20.35	22.90	—11
December, 1890, to November, 1891	41.43	20.73	22.13	—6.4
MUSCONETCONG.				
June, 1890, to May, 1891	46.35	21.18	22.90	—7.5
December, 1890, to November, 1891	42.69	20.65	22.33	—7.5
RAMAPO.				
June, 1890, to May, 1891	54.43	24.96	24.22	+3.1
June, 1891, to May, 1892	41.95	22.79	22.22	+2.6
PEQUANNOCK.				
June, 1891, to May, 1892	42.80	19.78	22.35	—11.5
June, 1892, to May, 1893	48.74	19.88	23.30	—14.7

This group of streams shows some range of evaporation, reaching from about 5 per cent. less than that shown by the Passaic formulæ up to about 12 per cent. less. It appears that the higher water-sheds show less evaporation than the lower. The Climatology of New Jersey states that the temperature of the lower parts of Kittatinny valley probably averages two degrees higher than the Highlands, the ordinary allowance being one degree decrease of temperature for each 300 feet increase in elevation. Our mean annual temperature, from which we deduce the correction to the Passaic formulæ of minus 11.5 per cent., is probably near the average, and allowing for difference in elevation, the range which we note in our observed evaporation is readily accounted for. It appears, therefore, that if we would be on the safe side with these streams it will hardly do to allow more than 5 per cent. less evaporation than we found for the Passaic, Croton and Sudbury. As we take up each stream in detail, we may make proper variations from our average evaporation, as computed in Table No. 46. As should be expected, the Ramapo shows very nearly the same evaporation as the Passaic, being similarly situated to the average of the Passaic water-shed. The smaller water-shed of the Pequannock, lying high on the Highland plateau, shows somewhat less evaporation. As we have before remarked, it is highly probable that it is this decreasing temperature over increased elevation, and consequently decreasing evaporation, to which we must attribute the prevalent idea that the larger percentage of rainfall is available from mountainous water-sheds. We do not believe that the cause of this is that the rain runs off more rapidly to the stream, as by far the greater amount of work done by evaporation is accomplished when there is no rain falling. The greater bulk of water evaporated, by which term we include all water lost to stream-flow, is drawn from the earth either directly by the sun or indirectly through vegetation, and the amount is determined far more by the capacity of the air to take up moisture than by the peculiarities of the topography of different water-sheds. The only condition which would produce considerable increased evaporation would be, that a very large proportion of the water-shed was included in the surface of lakes and ponds, or in marshes so wet that the water should stand over them in shallow pools. The above indications warn us that we cannot entirely ignore considerable differences in the general elevation of the water-shed.

TABLE No. 48.

Comparison of Raritan and Other Red Sandstone Plain Gaugings.

Period.	Rain.	Observed Evaporation.	Computed Evaporation for Passaic.	Difference. Per cent.
RARITAN.				
December, 1890, to November, 1892..	42.85	22.33	22.35	+5.6
December, 1891, to November, 1892..	43.97	25.05	22.54	
December, 1892, to November, 1893..	49.67	23.86	23.46	+1.7
HACKENSACK.				
Year ending with October, 1884.......	44.84	26.53	22.69	
Year ending with October, 1885.......	41.70	27.34	22.17	
Year ending with October, 1886.......	44.00	26.42	22.52	
Year ending with October, 1887.......	48.09	28.68	23.18	
Year ending with October, 1888.......	52.52	20.27	23.91	
Year ending with October, 1889.......	57.74	21.64	24.75	
Year ending with May, 1891............	53.08	20.67	24.00	
Year ending with May, 1892............	38.43	20.88	21.65	
Totals		191.83	184.87	+3.8

The Raritan shows an average excess of 4.2 per cent. over the Passaic evaporation. The Hackensack shows a considerable variation because of large flow from ground-water, but the average evaporation for eight years is 3.8 per cent. over the Passaic. Our excess deduced from temperature is 5 per cent., which is a satisfactory agreement within the probable limits of error of the observations.

TABLE No. 49.

Comparison of Delaware Gaugings.

Periods.	Rain.	Observed Evaporation.	Computed Evaporation for Passaic.	Difference. Per cent.
December, 1890, to November, 1891..	44.94	18.67	22.68	—17.7

This shows rather less evaporation than our temperature data indicate. Our computed correction was 11.5 per cent. It suggests that our computed average evaporation may be rather more than the actual, therefore our computed flows will be somewhat smaller and on the safe side.

TABLE No. 50.

Comparison of Great Egg Harbor and Batsto Gaugings.

Period.	Rain.	Observed Evaporation.	Computed Evaporation for Passaic.	Difference. Per cent.
GREAT EGG HARBOR.				
June, 1890, to May, 1891................	54.52	30.27	24.30	+25.0
December, 1890, to November, 1891..	53.65	29.66	24.60	+20.6
December, 1891, to November, 1892..	47.92	30.44	23 20	+31.2
June, 1891, to May, 1892..........	50.38	27.41	23.60	+16.1
BATSTO.				
June, 1891, to May, 1892................	49.19	26.97	23.40	+15.2

The computed excess over Passaic evaporation on these streams was 14 per cent. The above shows an average excess of 21.6 per cent., equivalent to a difference of about four degrees in mean temperature. All of these streams are gauged at dams, and in this loose sand a considerable amount of water undoubtedly finds its way out around and under the dams. It is also a fact that an amount which is indeterminate follows down the sandy strata underlying the watersheds, all of which dip toward the sea at the rate of about twenty-five feet per mile. This water finds its way to the sea without reaching the streams at all. These two combined leakages may possibly account for the average difference of 1.81 inches per annum, and we do not believe that the actual evaporation can much exceed what we have allowed, 14 per cent. in excess of that of the Passaic, Croton and Sudbury. We are further confirmed in this opinion by the observed fact that the excess of observed evaporation seems as large during the winter as during the summer months. It tends to a constant throughout the year.

In the foregoing comparison we must not expect too close an agreement. It would be better if we could take the time to compare month by month, for the evaporation computed by the yearly formula alone cannot be entirely accurate. The actual evaporation in a given year depends not alone upon mean temperature and amount of precipitation, but upon the distribution of that precipitation through the months. If it is heavy in the hot months the evaporation will be greater, and *vice versa.* The annual evaporation for a given year can only be obtained accurately by computing it month by month and adding the results. Nevertheless, the above computation is approximate and sufficient for our present purpose.

Having the above data, it only remains for us to determine the ground-water curves for the various typical streams of the State in order to enable us to compute the average, ordinary dry and driest-season flow, the rainfall for the average year being taken from Table No. 2, the ordinary dry year from Table No. 5 and the driest period from the above Philadelphia record of 1881 and 1882. We obtain these curves of ground-flow from our various series of gaugings of New Jersey streams which appear at the beginning of our discussion of each class of streams of the State in a later part of the report, by means of an analysis similar to that which we made for the Sudbury in Table No. 34. Bearing in mind the circumstances which go to make up larger or smaller ground-flow from a water-shed, it is apparent that we cannot follow out the same classification of streams which we adopted for rainfall and evaporation in selecting our ground-flow types. Streams which are similar in the topography of their water-sheds and in their underlying rocks must be grouped in the same class in ground-flow. The water-sheds of the State lying north of the glacial moraine will generally show somewhat larger ground-flow than streams of the same type whose water-sheds are not covered by glacial drift, while all of the southern New Jersey streams will come in the same group. In working out these ground-flow curves, I have found those already worked out for the streams of which we have long-series gaugings very useful as guides. Gaugings for a single year which embraces a good, dry period are sufficient to enable us to determine the principal characteristics of the flow from ground-storage for a given stream. In fact, even gaugings for a single month during the dry season are an aid to the selection of the proper type of ground-flow curve.

I have found that in general the depletion of ground-water does not exceed about 7.5 inches. The minimum gaugings which are given in Table No. 42 may easily, with safety, be attributed to this ground-flow depletion of 7 inches. Such minimum gaugings indicate the minimum monthly flow of the stream fairly well, and consequently they are a valuable guide in selecting the proper type of ground-flow curve. We would warn the reader, however, that it is best not to put too great confidence in a single record of minimum flow, nor even in a series of gaugings which do not cover more than a single year. In such cases it will be safest to be guided by the general character of the water-shed, and to select a curve adapted to the topographical and geological conditions which exist. The ground-flow curve becomes important in estimating the dry-season flow, but for water-supply purposes, where the water is to be stored, there is no danger of any serious error in making this selection. In cases where works are depending upon the dry-season stream-flow without storage, much care needs to be used in this selection.

Plate VI. gives the several types of curves which occur in New Jersey. A curve may here be found suited to every case of importance which we shall meet in the State. In dealing with very small streams, a wider variation of ground-flow is met with than is the case with larger water-sheds. If a small water-shed lies so high, or so much on a slope that the ground-water is drawn to a level lower than that of the stream-bed, the stream will run entirely dry and such conditions may occur in any kind of rock. If, on the other hand, such small streams have their beds at a level considerably below the general level of their water-shed, they may furnish a phenomenally-large ground-flow. The mere inspection of the water-shed will determine to which class such a stream belongs, whether of large or small ground-flow.

METHOD OF COMPUTING FLOW.

Having selected our ground-flow curve, we take from Table No. 46 our rainfall and evaporation for each month of the average, the ordinary dry, and the driest years pertaining to the regions in which the stream is situated, and, beginning with December, we may with safety take the flow to be the difference between rainfall and evaporation for

Plate 6a.

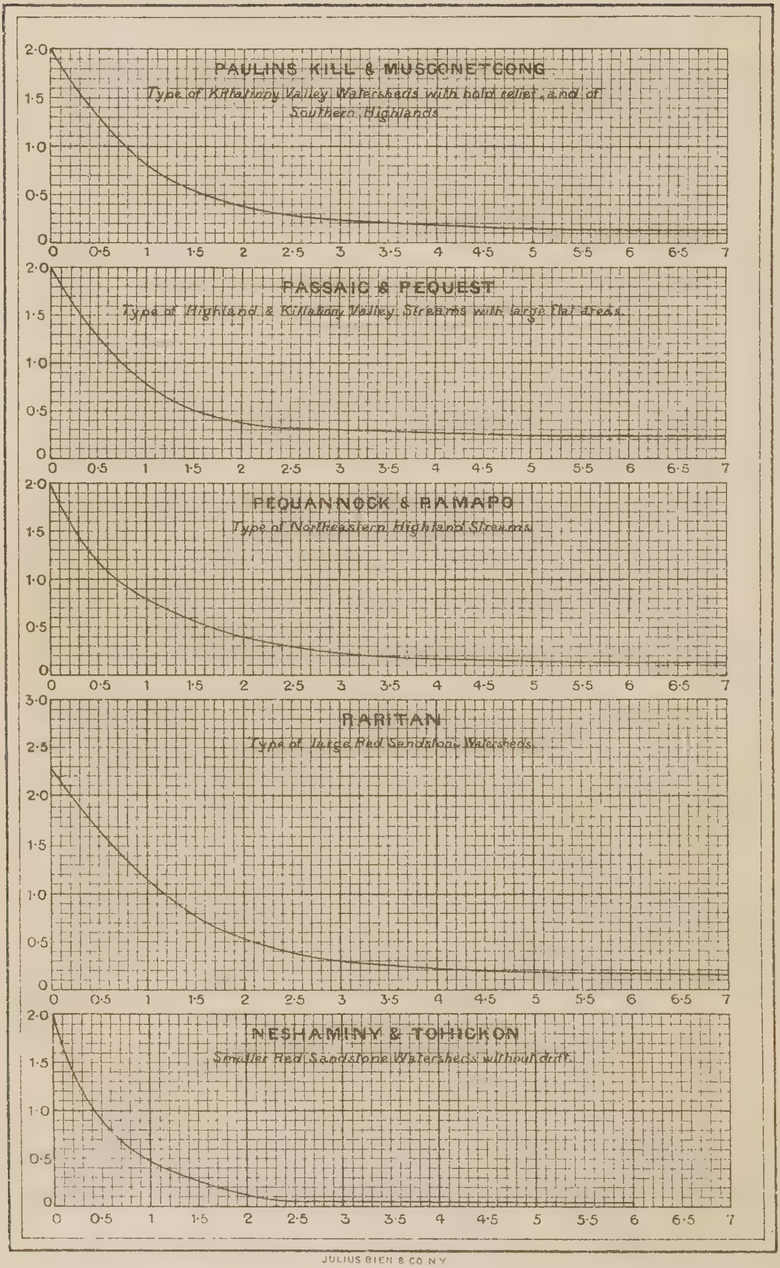


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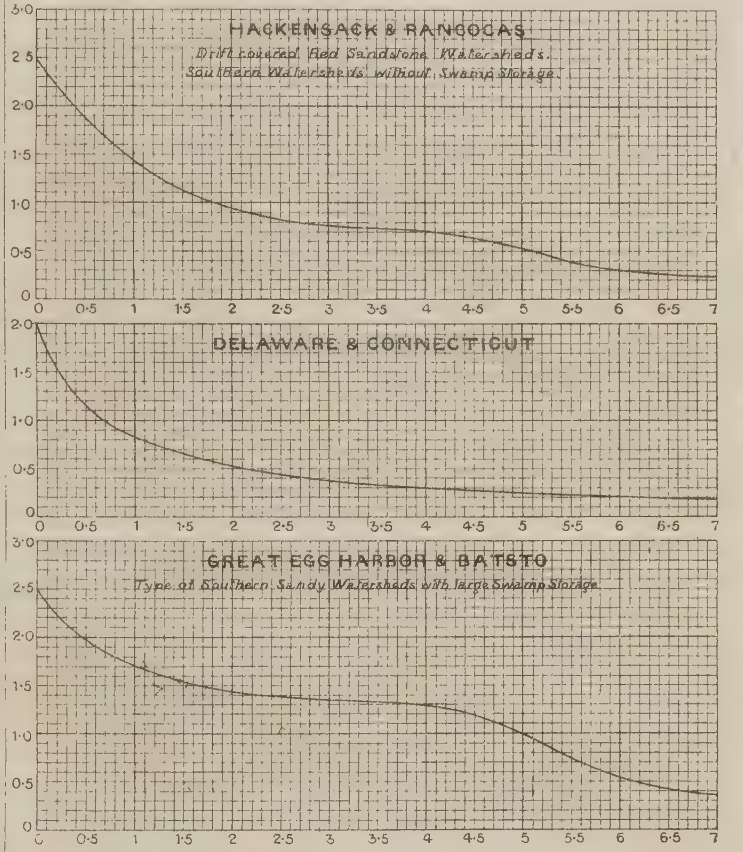
Plate 6 b.



DIAGRAMS SHOWING
GROUND FLOW OF NEW JERSEY STREAMS
FOR A GIVEN DEPLETION.

Figures at bottom show average depletion of ground water during month in inches, and figures at left the monthly flow of stream corresponding to such depletion.

JULIUS BIEN & CO N.Y.
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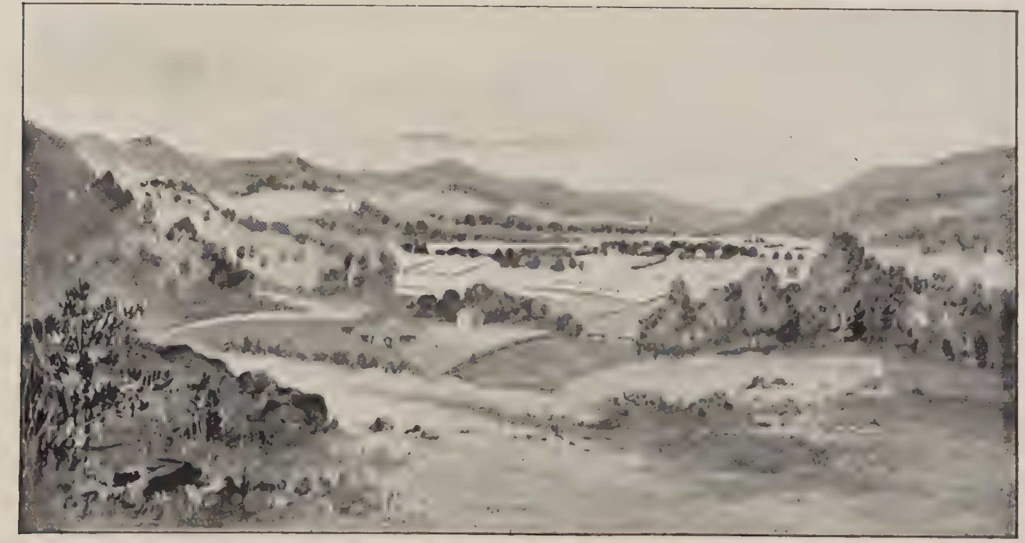
each month until April, since during this period the carrying over of snow and ice and the frozen state of the ground make it of little importance to take into account the flow from ground-water. Beginning with April, however, we need to exercise more vigilance, and in any month when the difference between rain and evaporation becomes less than two inches the ground-flow curve must be brought into use, and its use continued until the ground-water again becomes replenished. We have already sufficiently explained the method of procedure when the ground-flow diagram is in use. We have adopted this method in all our computations of the flow of New Jersey streams which follow. It may be again remarked that our computations, although they come very near to the actual flow, in some cases neglect a certain percentage of irregular surface-flow, which may occur at times when the rainfall is highly concentrated, or the surface of the earth is in a less than usual absorbent condition, because of freezing or other unfavorable conditions. Even when such is the case, the method is so continuous that any deficiency arising from such cause will appear as a corresponding excess in one or more later months, and the practical result will not be seriously affected. In dealing with the streams of the State hereafter, it will be necessary to adopt a slightly more detailed classification than we have used heretofore. It will be seen that the stream-flow is affected by differences in rainfall, evaporation, and finally in topographical and geological conditions which affect the ground-flow, and only such streams as agree in all of these respects can be dealt with as one class. Where any important number of streams can be brought into a group this has been done, in order that remarks and generalizations which apply to all may be made with as great saving of space and avoidance of repetition as is possible. The reader will find in the appendices tables of drainage areas, a list of water-powers, and much other matter pertaining to all the streams which are hereafter discussed.

KITTATINNY VALLEY AND HIGHLAND STREAMS.

For a detailed description of the topography of this and the other classes of water-sheds which we shall hereafter treat of, the reader is referred to Volume I. of the Final Report, published in 1888, which contains a full topographical description of the State. The shorter descriptions which we shall give here are intended to serve ordinary purposes and cover points which are not always included in the report referred to. The rainfall used with the gaugings has been obtained by averaging two or more stations of the New Jersey State Weather Service, and we shall here acknowledge our indebtedness to this service for valuable data which we could not otherwise have obtained. No matter how good they may be, stream gaugings without temporary rainfall measurements are absolutely worthless for the accurate estimation of the probable flow of a stream during periods of extreme drought. For purposes of water-supply, the yield of a stream is determined by its yield during the driest period, and we have, in each case, given what we believe to be the very largest amount which can safely be collected by storage from each class of water-sheds. Our figures for horse-power always refer to gross or theoretical horse-power, unless otherwise stated. In accordance with ordinary practice, we have taken the available horse-power to be the amount which will be at all times available during nine months of the ordinary dry year. We find that the available horse-power will be available for about 9 months in 12 excepting once in fifty years, and that it will be available throughout the whole of an average year, or for more than one-half of the time. In our detailed studies of each stream, we shall show from time to time how this theoretical available horse-power compares with the amount actually utilized.

Kittatinny valley and the Highlands, including the boldest topography in the State, generally range from 500 to 1,500 feet in elevation. We have selected two types for our estimates of the flow of these streams. The first, or ordinary, includes the Paulinskill, Musconetcong, North Branch of the Raritan and most of the Passaic headwaters. It is the ordinary type. The estimated flow for this class of streams is given in Table No. 51. The second type includes such streams as the Pequest, the upper part of the south branch of the Raritan and others which have flatter water-sheds and a considerable amount of sand and gravel therein, giving a larger flow from ground-water. Such streams are the most valuable for water-power, as they give a larger flow during the extreme dry months, but, notwithstanding this fact, the actual amount of available horse-power determined by our rule is no greater than on the first class of streams.



KITTATINNY VALLEY TOPOGRAPHY—VERNON VALLEY AND POCHUCK MOUNTAIN.

TABLE No. 51.

Estimated Flow of Kittatinny Valley and Highland Streams with Ordinary Water-Sheds.

	December.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	Year.
AVERAGE YEAR.													
Inches of rainfall	3.57	3.48	3.31	3.57	3.48	3.88	3.88	4.05	4.42	3.57	3.31	3.57	44.09
Inches flowing off	2.97	2.93	2.75	2.83	2.39	1.80	1.27	.82	.76	1.11	1.71	2.67	24.41
Flow in thousand gallons daily per square mile	1,663	1,640	1,645	1,585	1,385	1,009	735	459	426	643	958	1,545	1,162
Horse-power on one foot fall per square mile	.291	.287	.289	.278	.244	.178	.130	.081	.075	.113	.169	.272	.205
ORDINARY DRY YEAR.													
Inches of rainfall	3.86	3.94	1.64	2.89	2.55	3.29	3.66	4.35	3.83	.96	2.04	2.19	35.20
Inches flowing off	3.07	3.36	1.23	2.21	1.86	1.35	1.00	.76	.70	.45	.39	.65	17.03
Flow in thousand gallons daily per square mile	1,720	1,880	775	1,240	1,075	751	579	426	392	261	218	377	811
Horse-power on one foot fall per square mile	.303	.332	.129	.218	.190	.105	.102	.075	.069	.046	.038	.066	.143
DRIEST PERIOD.													
Inches of rainfall	4.05	3.66	4.76	3.83	.61	2.71	3.87	.96	1.18	.94	3.04	2.02	31.63
Inches flowing off	3.31	3.09	4.07	3.07	1.10	.60	.65	.27	.17	.14	.15	.20	16.82
Flow in thousand gallons daily per square mile	1,850	1,730	2,435	1,720	636	336	377	151	95	81	84	116	801
Horse-power on one foot fall per square mile	.326	.305	.428	.303	.112	.059	.066	.026	.017	.014	.015	.204	.141
Continued.													
Inches of rainfall	2.63	4.57	4.22	3.57	2.12	5.06	1.90	1.37	6.40	12.09	1.32	.99	46.24
Inches flowing off	.32	2.79	3.58	2.83	1.64	2.03	.94	.28	.30	7.27	1.35	.70	24.03

Storage needed to utilize 14 inches per annum, or 666,094 gallons daily per square mile, will be 7 inches, or 121,642,752 gallons per square mile. In the driest period such reservoirs would not be full from April to September, a period of 18 months. For 9 months of an ordinary dry year, and about 94 per cent. of the whole time, .069 theoretical horse-power will be available on one foot fall for each square mile of water-shed.

TABLE No. 52.

Estimated Flow of Kittatinny Valley and Highland Streams with Flat, Drift-Covered Water-Sheds and Large Ground-Flow.

AVERAGE YEAR.

	December.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	Year.
Inches of rainfall	3.57	3.48	3.31	3.57	3.48	3.88	3.88	4.05	4.42	3.57	3.31	3.57	44.09
Inches flowing off	2.97	2.93	2.75	2.83	2.39	1.80	1.33	.76	.74	1.07	1.77	2.67	24.41
Flow in thousand gallons daily per square mile	1,660	1,640	1,645	1,585	1,385	1,020	770	426	414	620	990	1,545	1,162
Horse-power on one foot fall per square mile	.293	.290	.289	.280	.244	....	.136	......	......	.109	......	.272	....

ORDINARY DRY YEAR.

	December.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	Year.
Inches of rainfall	3.86	3.94	1.64	2.89	2.55	3.29	3.66	4.35	3.83	.96	2.04	2.19	35.20
Inches flowing off	3 07	3.36	1.23	2.21	1.78	1.39	.99	.76	.68	.45	.39	.64	16.97
Flow in thousand gallons daily per square mile	1,720	1,880	775	1,240	1,030	780	573	426	381	261	218	371	810
Horse-power on one foot fall per square mile	.303	.332	.129	.218	.182	.137	.101	.075	.067	.046	.038	.065	.143

DRIEST PERIOD.

	December.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	Year.
Inches of rainfall	4.05	3.66	4.76	3.83	.61	2.71	3.87	.96	1.18	.94	3.04	2.02	31.63
Inches flowing off	3.31	3.09	4.07	3.07	1.08	.59	.63	.33	.32	.25	.25	.28	17.27
Flow in thousand gallons daily per square mile	1,850	1,730	2,435	1,720	605	331	365	185	179	145	140	162	825
Horse-power on one foot fall per square mile	.326	.305	.428	.303	.110	.058	.064	.033	.032	.026	.025	.029	.145
Continued.													
Inches of rainfall	2.63	4.57	4.22	3.57	2.12	5.06	1.90	1.37	6.40	12.09	1.32	99	46.24
Inches flowing off	.32	2.24	3.58	2.83	1.64	2.03	.94	.32	.33	7.20	1.35	.70	23.48

The storage needed to utilize 14 inches per annum, or 666,094 gallons daily per square mile, will be 6.45 inches, or 112,098,000 gallons per square mile. For 9 months of an ordinary dry year, and about 94 per cent. of the whole time, .067 theoretical horse-power will be available on one foot fall for each square mile of water-shed.

FLAT BROOK.

Beginning at the most northerly point of the State and passing down Delaware river, the first stream of any importance tributary to the Delaware from New Jersey is Flat brook. Its source is near High Point, in the Kittatinny mountains, 21 miles from its mouth. Its water-shed has an area of 65.7 square miles, 54 per cent. of which is in forest. The population is 21 to the square mile. This area lies entirely upon the west slope of Kittatinny mountain, being nearly six miles wide near the source and two and one-half miles near the mouth. The stream rises quickly, floods passing over in about 36 hours. We have no gaugings, but estimate the maximum flow to be about 60 cubic feet per second per square mile. The stream gets very muddy in time of floods. Its flow is that shown in Table No. 51.

Water-supply.—This stream is of no importance as a source of domestic water-supply. It is remote from all probable demand, and there are few opportunities for storage, excepting in the lower valley.

Water-power.—From Table No. 51 we estimate the available power on seven feet fall at the grist mill at Peter's Valley to be 24.15 horse-power. Table No. 51 shows the available horse-power for nine months of an ordinary dry year to be .069 horse-power per foot fall for each square mile. We find the horse-power actually in use here is 23. In the same way we estimate the available power at Flatbrookville to be 4 48 horse-power for each foot of fall. As the Delaware rises some 32 feet in great floods at this point, water-powers developed near the mouth will be liable to drowning occasionally from back-water. About 40 feet fall could be utilized at a point one and one-half miles above Flatbrookville. This site is at present inaccessible, but a railroad is projected to pass through the valley on the Pennsylvania side of the Delaware, which will improve the facilities for transportation. The amount of power actually in use upon the stream at present is shown in the table of water-powers in Appendix I.

PAULINSKILL.

This stream lies in the main axis of the Kittatinny valley, which it drains for 25 miles, from Augusta southwestward to the Delaware. The lower 18 miles of the water-shed is quite uniform in width, averaging 7 miles, with its western border on Kittatinny mountain from 1,000 to 1,200 feet above the stream, and its eastern border on a slate ridge about 400 feet above. The upper part widens out to 12 miles and has some swampy areas, which have been partially drained. The fall for the first 10 miles from the mouth averages 7 feet per mile, with little variation; for 20 miles above this it is 8.5 feet per mile, also very uniform. The distance by the stream from the remotest source to the mouth is about 36 miles. The bottom of the valley is blue limestone; the higher portions of the shed mainly slate. About 25 per cent. of the area is in forest. Much of the lower portion is in permanent pasture, while the ridges are devoted to general farming.

Swartswood and Culver's lake have both been utilized as reservoirs for mills, and are controlled for a depth of 4 to 5 feet, with extreme variations in height of 5.5 feet at Swartswood and 6.5 feet at Culver's. These and other lakes on the water-shed represent a total storage of 0.7 inch on the entire water-shed, which storage is allowed to flow pretty freely to feed the respective mills. This and the additional storage afforded by the meadows near Newton account for a very large first-month storage flow.

From flood-marks at Hainesburgh, the flood-discharge seems to be limited to 4,126 cubic feet per second, or 23 cubic feet per second per square mile of water-shed. The long, narrow shed below, and flatness of the upper, broad portion, favor a gradual discharge of surface-water. In cases of single heavy showers, the time from the height of the shower to the height of the flood at Hainesburg does not exceed 24 hours. The duration of flood-flows is from 4 to 8 days, although the water is not over the river banks much more than one-quarter of this time. The discharge reaches 1,800 cubic feet per second before the banks are overtopped, or about 10 cubic feet per second per square mile.

The dry-season flow, determined from data as to the run of mills in extreme droughts, ranged from 0.126 to 0.130 cubic feet per second per square mile, agreeing well with observed minima for other Highland and Kittatinny valley streams.

A gauge was set up at the mill of Messrs. G. C. Adams & Co., at Hainesburgh, about 25 miles above the mouth of the stream, and read by Mr. A. D. Cornell. There is a small amount of leakage through the dam, but not enough to cause any serious error. There are several mills above, but none of them have very large ponds, and while they hold back some water, it is not probable that the minimum flow for any week is very much reduced thereby, although the observed minimum for a single day probably is.

The accompanying table gives the flow by months, in inches, on the water-shed, and also the maximum, minimum and average flow in cubic feet per second:

FLOW OF THE PAULINSKILL, 1890–1891.

Water-shed, 174.8 square miles.

MONTH.	Rain—Inches	Flow—Inches.	FLOW IN CUBIC FEET PER SECOND.		
			Greatest.	Least.	Average.
1890.					
February 12th to 28th	1.97	1.58	655	272	437
March	6.15	4.44	1,894	317	672
April	2.81	2.88	996	272	451
May	6.58	3.88	1,219	229	470
June	3.42	2.29	726	146	357
July	5.30	.71	229	43	108
August	5.21	.73	597	29	112
September	4.01	1.60	726	111	249
October	5.17	2.31	868	165	352
November	.69	1.20	423	95	188
December	3.07	.66	230	63	99
1891.					
January	7.43	4.45	2,884	77	670
February	3.87	4.53	1,894	372	761
March	3.81	3.56	996	293	540
April	2.24	1.64	476	111	258
May	2.26	.60	146	50	90
June	1.85	....	....	....	....
July	4.20	....	....	....	....
August	5.20	....	....	....	....
September	2.05	....	....	....	....
October	3.29	....	....	....	....
November	2.33	....	....	....	....
December	4.43	1.02	476	55	....
1892.					
January	4.64	3.68	1,527	183	559
February	1.04	.95	272	77	154
March	4.19	1.80	560	146	274
April	1.40	1.11	272	111	174
May	5.27	1.09	423	50	166
June	5.68	1.82	1,578	111	286
July	3.30	.47	183	40	71

	Rain—Inches.	Flow—Inches.
June to November, 1890	23.80	8.84
December to May, 1891	22.68	15.44
June to May, 1890-1891	46.48	24.28
December to May, 1892	20.97	9.65

For the single full year shown in the above gaugings, the flow appears to be remarkably like that of the Croton, Sudbury and Passaic for the same amount of rainfall. These gaugings, like several others given hereafter, serve mainly to satisfy us that the streams obey our general law of evaporation and flow, and also to fix for us the peculiarities of ground-flow.

The Paulinskill flow is that shown in Table No. 51.

Water-supply.—This stream does not promise to ever become important as a source of domestic water-supply. Distance from probable demand, comparatively low elevation, the agricultural character of the water-shed and consequent roiliness in time of flood, together with a possible hardness of waters from the limestone bottoms, all contribute to make it, as a whole, less desirable than some other streams. Some branches may be excepted from these statements, as we shall see when we come to consider them later.

Horse-power.—Baleville is the first point where the stream becomes of considerable size by the junction of the east and west branches. The water-shed above this point is 66.3 square miles, consequently we find by Table No. 51 that the available power for 9 months of the ordinary dry year is 4.57 horse-power per foot fall. The mills here actually utilize from 6.66 to 11.03 horse-power for each foot fall, but there is not more than our estimated power steadily in use. Below the mouth of Swartswood lake branch the water-shed becomes 102 square miles, and we estimate the available horse-power at Stillwater to be 7.04 for each foot fall. From 5 to 5.7 is actually utilized. The fall from Baleville to Stillwater is 70 feet, 28 feet of which is improved. Near Swartswood and Emmons stations, on the New York, Susquehanna and Western railroad, sites with about 12 feet fall each and about 54 available horse-power might be improved. At Paulina we estimate the available power to be 8.07 horse-power per foot fall. About 10 horse-power is actually in use. It should be noted here that our estimated power is for 24 hours daily, whereas the succession of mill-ponds along the stream afford storage enough to concentrate the entire power into working hours, consequently more power than our estimate can be utilized from 12 to 14 hours per day. Between Stillwater and Paulina, 42.5 out of 70 feet is improved. The remaining fall is much divided, and can scarcely be utilized except by increasing the fall of existing sites. There is, however, an unused grist-mill site with 9 feet fall at Paulina which should furnish 72 horse-power by our table. The water-shed here is 117 square miles. At Hainesburgh we make the available power 12.07 horse-power per foot fall. The amount improved is 16 horse-power per foot fall, which is said to be satisfactorily used. Between Paulina and Hainesburgh we have 40 feet of unused fall, good for about 400 gross horse-power. This could probably be utilized at three or four sites. Below Hainsburgh the fall is all developed. The grist-mill at Warrington has 8 feet fall, and we estimate 96 available horse-power. Something more than this is actually required to run the present mill, which has a low efficiency. At Columbia there is an unused saw-mill site with 13 feet fall and 156 available horse-power.

Swartswood lake.—This lake is utilized for storage for the mill of John W. Kean, Esq., on the outlet. The extreme variation between low and high-water levels is 5.5 feet, representing a storage of 121,000,000 cubic feet. Even with the large storage, the flood-flow at the outlet has reached 1,070 cubic feet per second, or 65.8 cubic feet per second per square mile of water-shed. With this great storage, the power at the outlet is a very good, reliable one, always sufficient for three run of stone on 17 feet head. The water-shed is 16.3 square miles, and this is a good example of successful utilization of a small water-shed for power by means of storage.

The storage amounts to 3.16 inches upon the water-shed. It is, consequently, enough to maintain a flow of 0.70 inch monthly, even in the driest year, and as this flow can be concentrated into working hours, 2.25 horse-power per foot fall will always be available at the outlet for 12 hours daily. This is now utilized on 17 feet fall, but it would seem feasible to obtain 55 feet by a raceway about half a mile in length, giving a very reliable power of 124 horse-power.

This water-shed might also be utilized for water-supply, for which it is much better adapted than the main Paulinskill. With the present storage, it would supply 6,500,000 gallons daily. With storage equal to 7 inches upon the water-shed, it will afford a supply of about 11,000,000 gallons daily. The elevation is 482 feet. The area of the lake is 505 acres.

Culver's lake, at Branchville, is also utilized for storage for mills It has a storage capacity between extreme levels of 137,000,000 cubic feet. The area of the lake is 486 acres; its drainage area is 6.3 square miles. Within this same water-shed is Long pond, with an area of 299 acres and 2.5 square miles of drainage. Culver's lake may be drawn off 6 feet and affords about 8 inches storage upon the water-shed. In addition to this is the natural storage of Long pond. There is some 300 feet fall in the 2 miles from the outlet to Branchville. With the above storage, there is always available 0.74 horse-power per foot fall. Ten mills utilize 205 feet of the available fall, but 5 of these are not in use. About 1.8 horse-power per foot fall is actually in use. As our 0.74 horse-power computed is concentrated into working hours, it becomes 1.48 horse-power, consequently these mills have steady, reliable power. It would appear that in this case it might be easy to transmit the power of these several plants, electrically, to a single point in Branchville, utilizing 250 feet fall and 185 horse-power continuous, or 370 horse-power in working hours. In this way the present inaccessibility of several of the mills would be obviated. These powers have been highly regarded in the past, and no doubt justly, as our estimates show. It is an admirable instance of a large amount of power obtained from a small water-shed with high fall, by storage.

Culver's lake is at 850 feet elevation. It would afford a good domestic supply of 4,200,000 gallons daily with the present storage.

Although a considerable amount of power is developed at Lafayette, on the eastern branch, the other branches of the Paulinskill do not call for special comment.

Passing down the Delaware, the next stream of importance is met at Belvidere.

PEQUEST RIVER.

This stream lies at the eastern side of the Kittatinny valley. In the midst of its water-shed, Jenny Jump mountain, a ridge of gneiss, rises and covers some 17 square miles, the total area of the water-shed being 158.2 square miles. The southern and eastern border of the area is also on the gneiss, but most of it lies upon the blue limestone, and 30 square miles of this is very level, the remainder of the water-shed being of about the same slope as the Paulinskill. The length of the main stream is 32 miles from its remotest source, near Pinkneyville, to its junction with the Delaware river at Belvidere. Its principal affluent is Beaver brook, which comes in from the north 2 miles from the mouth and drains 37 square miles. The fall of the main stream for the lower 10 miles is 27 feet per mile; for 4 miles above this it is 2.5 feet per mile; and this brings us to the outlet of the great Pequest meadows, which were drained some years since. These meadows have an area of about 8 square miles, and before being drained they were extremely wet, under water much of the time, but they are now being brought under cultivation. In 1885 they were nearly half in timber, but this is now being cut off. The fall of the stream for 5½ miles through these meadows is 4 feet per mile; the next 6 miles have a fall at the rate of 4.5 feet, and the valley continues nearly level to the source of the stream, which flows through a chain of small lakes. There is much drift on the basin, as it is crossed by the terminal moraine. Forest covers 18 per cent. of the shed. A gauge was set up at Belvidere and read first by Mr. Clinton Cole, and later by Mr. I. B. Keener.

FLOW OF PEQUEST RIVER.

Drainage area, 158 square miles.

MONTH.	Rain—Inches.	Flow—Inches.	FLOW IN CUBIC FEET PER SECOND.		
			Greatest.	Least.	Average.
1890.					
February 12th to 28th	1.96	1.62	561	286	405
March	6.15	3.97	1,016	290	544
April	2.81	3.34	796	264	459
May	6.58	3.07	584	209	425
June	3.42	2.43	505	100	344
July	5.30	.96	319	58	127
August	5.21	....	....	....	....
September	4.01	....	....	....	....
October	5.17	2.17	428	145	306
November	.70	1.47	312	132	208
December	3.07	1.08	327	95	149
1891.					
January	7.43	4.27	1,253	119	587
February	3.87	3.99	842	397	607
March	3.81	3.74	757	312	513
April	2.24	1.82	439	107	260
May	2.09	.71	154	63	98
June	1.85	.78	222	54	111
July	4.20	.70	197	56	97
August	5.20	.81	272	38	112
September	2.05	.80	173	43	114
October	3.29	.97	272	81	134
November	2.33	1.03	426	64	146
December	4.43	2.69	694	76	371

	Rain—Inches.	Flow—Inches.
June to November, 1890	23.81	10.36
December to May, 1891	22.51	15.61
June to November, 1891	18.92	5.09
June, 1890, to May, 1891	46.32	25.97
December, 1890, to November, 1891	41.43	20.70

Comparing these gaugings with those for the Paulinskill, they are found to show always larger flow in the dry months, but very similar results in the aggregate. In short, the flow from ground-storage after the first two or three months of depletion is better sustained on the Pequest. The ground-flow curve derived from Passaic gaugings was found to agree well with these gaugings, and was adopted for Highland and Kittatinny valley streams of this type, the resulting estimated flow being shown in Table No. 52. Referring to this table, we find all the data of flow, therefore, for the Pequest.

The surface-flows show much less fluctuation than on the Paulinskill. The floods do not reach a great height, and require more time to discharge. The waters from the lower part of the main stream, where the slopes of stream and water-shed are steep, discharge first and are out of the way before the slow-moving floods from the flat upper shed have come down. The height is reached at Belvidere in about 36 hours, but the waters are not discharged in less than from 7 to 10 days. The contracted outlet and small preparation for heavy flood-discharges are noticeable at Belvidere. The highest flood-marks pointed out indicate a flow of 1,996 cubic feet per second, 12.5 per square mile, and this must be the extreme limit. This is a light discharge for northern New Jersey.

At Ketcham's mills, one mile below Townsbury, the flood is said to reach its height in from 12 to 24 hours, remain high for two days and then recede slowly. Mr. Ketcham thinks the river is more fluctuating than it was before the drainage of the Pequest meadows, and gets lower in summer. Mr. John Green, at the mill just above, thinks that the drainage has improved the summer flow of the stream, as there is less loss from evaporation than from the great overflowed area of former years. The majority of the mill-owners seem to hold the latter opinion. The maximum discharge at Townsbury seems to be about 800 cubic feet per second, on 83.4 square miles of water-shed; about 9.6 cubic feet per second per square mile. As this point is at the outlet of the flat upper shed and the steeper parts are not involved, it appears to agree well with the observed discharge at Belvidere.

The dry-season flow here has been estimated from the run of mill to be about 14 cubic feet per second. This was in the great drought of 1881. The rate would be 0.17 cubic feet per second per square mile.

At Tranquility the maximum flood-flow indicated is 650 cubic feet per second, or 18.7 per square mile. At Huntsville, the greatest known discharge was 605 cubic feet per second, or 19.3 per square mile. These last two places are both above the Great Meadows, and the increase of flood-flow over Townsbury is apparent, but the drainage area is still very flat. The flood at Huntsville, referred to, remained very high for two days. The river does not get very muddy in floods.

Green's pond has a capacity of 10,000,000 cubic feet between its extreme levels. This is all natural storage. Hunt's pond is utilized for storage for the mill of T. F. Hunt, Esq., with a capacity of 7,245,000 cubic feet. Allamuchy pond is also utilized, with 27,000,000 cubic feet capacity. The flood-flow at its outlet is 40 cubic feet per second for 1.7 square miles of steep water-shed on Archean rock. With the same area on slate rock, with gentler slopes, Hunt's pond gives a maximum of 43 cubic feet per second. This is another good example of the utilization of a very small water-shed for power by means of storage. Mr. Hunt has always enough power for one run of stone in the dryest weather on 30 feet fall.

Water-supply.—The Pequest has little value as a source of public water-supply. It is generally less roily than the Paulinskill in time of flood, but it drains an agricultural country, largely limestone and very flat. The water may be expected to be rather hard, and the facilities for storage are extremely poor. Considering its remoteness from the probable demand, its elevation is also low. It is by no means as desirable as the main Delaware itself.

Water-power.—Its large ground-flow makes the Pequest one of the most desirable of the Kittatinny valley streams for water-power. The facilities for transportation are good, the Lehigh and Hudson River railroad following the entire course of the main stream.

At Tranquility the available power is 2.33 horse-power per foot fall. The head here is 5 feet. There is very little fall available on this upper part of the water-shed. From Townsbury down to Belvidere, about ten miles, the total fall is 270 feet. At Townsbury the available power is 5.59 horse-power per foot fall. Nearly 11 is utilized with considerable pondage, but not more than the above-estimated power is ordinarily used. From here to Butzville there is 130 feet fall, 31 of which is in use. The rest could only be utilized by raceways. In half a mile 20 feet fall could be obtained at two or three points, the available power ranging from 5.59 to 7.70 horse-power per foot fall. From Butzville to the mouth of Beaver brook there is 70 feet of fall, of which only 6 is utilized. The available power here is 8 horse-power to a foot of fall, and some of this might be utilized near Bridgeville. Below the mouth of Beaver brook the available power is 10.45 horse-power per foot of fall. About 20 feet fall could readily be improved at this point, and a power of 210 horse-power developed. This is within 1.5 miles of Belvidere, where 42 feet fall is improved, with a use of 12.4 horse-power per foot fall.

Beaver brook.—This is the only important affluent of the Pequest. It has not much importance at present, being rather inaccessible, with few very good sites for mills. At Sarepta the available power is 2.34 per foot fall, and there is an unused mill site. At Hope the mill has 25 feet fall, and we make the available horse-power 0.63 per foot fall.

Pophandusing brook and *Buckhorn creek* belong to the class of streams the flow of which is given in Table No. 51. They are not important.

Lopatcong creek belongs also to the ordinary type of this class of streams. It is considerably utilized for power, but its flow is mingled with that from the Morris canal. Its headwaters above Harmony would be available for a small public water-supply.

At the mouth, there are evidences of a very heavy flood-flow, and also at Lower Harmony. It appears to be at the rate of about 133 cubic feet per second per square mile.

The minimum flow is apparently 0.38 cubic feet per second per square mile at Lower Harmony. The stream here issues from a narrow and very deep ravine in Scott's mountain, which accounts for a large ground-flow.

POHATCONG CREEK.

This stream drains an area 23 miles long, with an average width of 2.4 miles and an area of 56.2 square miles. The city of Washington is within its basin. Pohatcong mountain forms its southeast rim, rising from 400 to 500 feet above, and Scott's mountain its northwest border, rising from 600 to 800 feet. The valley is rolling limestone country, highly cultivated, and the ridges just mentioned are gneissic and generally wooded. The Morris canal traverses the basin for about 12 miles, and is said by the mill-owners to at times draw something from the flow of the stream. The leakage from the canal into streams is considerable. The flow of the Pohatcong is as shown in Table No. 51.

Water-supply.—By reason of its large population and agricultural character, the basin has little value as a gathering-ground for public water-supply. Some of the small branches, however, may have value for local gravity supplies of limited amount. Brass Castle creek is now used as a supply for Washington.

Notes of flow.—Near its mouth, the stream reaches flood-height in one day, remains high one day and runs down in about the same time, the duration of flood being about three days. On the lower part of stream, the maximum flow seems not to exceed 25 cubic feet per second per square mile. The minimum flow falls to about 0.14 cubic feet per second per square mile.

Water-power.—The stream is chiefly valuable for power, 493 gross horse-power being in use, mostly by grist or flouring mills. Five lines of railway afford transportation.

At Carpentersville, near the mouth, the available power is 3.86 horse-power per foot of fall. About 4 horse-power per foot fall is utilized at the saw-mill. At Springtown, 3.73 horse-power per foot fall may be had. An average of 4.1 is improved at the mills here. Between the saw-mill at Carpentersville and the next mill above, about 30 feet fall is unimproved. A power of 114 horse-power could be developed here. At Springtown and above, to Levi Cressman's mill, the fall is quite well utilized, and the developed horse-power is generally close to our estimated available power. Above Cressman's, the valley becomes flat and no facilities exist for the development of important power.

MUSCONETCONG RIVER.

This stream has a long, narrow water-shed in the Archean Highlands. The higher ground is Archean rock, quite well covered with soil; the valley bottom is limestone, with some slate in the foot-hills. The width at the mouth is 2 miles, very gradually increasing to 4 at Hackettstown, 26 miles up the valley, then narrowing to less than

3 to 6 miles farther up, at Waterloo. On these 32 miles of the course the stream flows at the southeast side of a very straight valley, above which the hills rise from 400 to 500 feet. Just above Waterloo the main stream comes into the valley from the plateau southeast, while the upper part of the straight valley is occupied by the principal affluent, Lubber's run. The combined sheds of the two forks widen out to 6 miles, and extend 12 miles northeast from Waterloo. This upper area is quite largely covered with drift, and is more wooded than the lower parts. Lubber's run has 87 per cent., and Lake Hopatcong 94 per cent. of its area in forest. On both branches there has been a considerable amount of storage utilized by the Morris canal to feed that water-way. Lake Hopatcong has a drainage area of 25.4 square miles, and has been raised by a dam at the outlet so as to give a storage of 1,100,000,000 cubic feet. This storage is used to feed the canal in both directions, so that some of the waters of the Musconetcong are diverted to the eastern slope of the State. "It is stated than the Stanhope mill has rights to the original power at the outlet, and that an opening of 10 by 36 inches is kept for the purpose of supplying the mill." (Newark Aqueduct Board, report on Additional Water-Supply, J. J. R. Croes and George W. Howell.)

Stanhope reservoir, two miles below, affords additional storage.

On Lubber's run, Cranberry reservoir and Bear ponds are utilized for storage. This complicates the flow of the stream somewhat. There is naturally much disagreement between the canal company and the many mill-owners on the lower part of this valuable water-power stream. It is evident, from the diagram of this year, that the flow has been kept up during the dry months by allowing some water to run from storage. How it may be in very dry years is not evident, of course. There is a marked difference of opinion among the mill-owners themselves as to whether they are benefited or injured by the storage. The table which appears below shows the effect of storage, not only in the dry-season flows, but in the cutting down of flood-flow, as compared with other streams.

The source of this stream is in the Sparta mountains, near the Pine swamp, 52 miles from the mouth. The fall for the lower 8 miles is 16 feet per mile; the next 22 miles, from Hackettstown to Bloomsbury, have 12 feet per mile; from the mouth of Lubber's run to Hackettstown, 8.5 miles, the fall is 16 feet per mile; while from Lake Hopatcong down to the valley of Lubber's run, the stream falls 55 feet per mile, for 5 miles.

At Finesville, it appears, from the statements of Messrs. Taylor, Stiles & Co., that the river has not run much lower in the previous six years than the recorded gaugings indicate. It requires four hours for the water to reach here from the mills just three miles above, which would indicate a velocity of 0.75 mile an hour. The maximum flood-flow, indicated by high-water marks here, is 1,960 cubic feet per second, about 12.8 per square mile, which seems very small, but is apparently correct. An ordinary flood discharges about 1,500 cubic feet per second. It should be noted that the extremely narrow lower shed and storage on the upper area both contribute to reduce the rate of discharge.

At Bloomsbury, Mr. F. G. Hoffman places his dry-season power at a rate equal to about 70 cubic feet per second.

At Imlaydale Mills, Mr. S. S. Cramer has a well-equipped mill which indicates a low-season flow of a little less than 56 cubic feet per second.

At Stephensburg, the mill can run two run of stone about all the time, indicating a flow of 35 cubic feet per second.

At Hackettstown, Mr. Lewis J. Youngblood reports that he has not stopped his mill more than 30 days since 1863 for lack of water. He runs three run of four-feet stones, on 9.5 feet fall, with a breast-wheel. He uses about 70 cubic feet per second, and has a considerable pondage. At the saw-mill above, 12 horse-power was obtained all through the drought of 1881, on 8 feet fall, indicating a flow of 26 cubic feet per second. The stream here is said to reach its height 24 hours after a heavy rain, and requires two weeks to run down to its ordinary stage. At Saxton Falls, where the Morris canal and the river finally separate their flows, the flood-flow of the river is 1,080 cubic feet per second, the water-shed being about 68 square miles. This is at the rate of 15.9 per square mile, a low rate, agreeing with that at Finesville.

A gauge was set up at Finesville, at the mills of Messrs. Taylor, Stiles & Company, and taken in charge and carefully read by these gentlemen. These gaugings are believed to be very close to the truth, the overfall being favorable to good results. Several gaugings of the Morris canal flow were also made. The accompanying table gives the results:

FLOW OF THE MUSCONETCONG AT FINESVILLE.

Drainage area, 155.8 square miles.

MONTH.	Rain—Inches.	Flow—Inches.	FLOW IN CUBIC FEET PER SECOND.		
			Greatest.	Least.	Average.
1890.					
February 12th to 28th	1.97	1.41	512	227	348
March	6.15	3.22	1,019	148	436
April	2.81	2.59	632	206	360
May	6.58	2.76	801	166	377
June	3.42	1.32	334	72	184
July	5.30	.83	265	61	113
August	5.21	.72	166	61	96
September	4.00	.83	357	61	117
October	5.17	1.20	334	89	167
November	.70	.80	188	72	113
December	3.07	.97	384	72	130
1891.					
January	7.43	4.69	3,172	87	633
February	3.87	3.66	1,350	385	551
March	3.80	3.25	713	124	440
April	2.24	1.52	334	104	212
May	2.14	.75	206	72	101
June	1.77	.48	104	47	67
July	4.33	.40	104	....	54
August	6.97	.67	499	....	92
September	1.55	.31	134	....	42
October	2.68	.23	72	....	29
November	2.84	.39	206	....	54
December	4.85	1.35	290	....	184
Total for 1891	44.47	17.70	....	....	....
May 1st, 1890, to April 30th, 1891	50.79	22.55	....	....	....

Our studies of Morris canal draught indicate that the reservoirs of Lake Hopatcong, Stanhope, Bear ponds and Cranberry reservoir practically utilize and divert the flow of 34 square miles of the above drainage during the year, or 22 per cent. of the whole. Correcting for this, we have the following results:

	Rain.	Gauged Flow.	True Flow.
June, 1890, to May, 1891	46.35	20.54	25.07
December, 1890, to November, 1891	42.69	18.08	22.04

This shows similar results to those of the Paulinskill and Pequest gaugings.

A detailed analysis of these gaugings shows that without storage the natural flow of the stream would be as shown by Table No. 51. Our estimates, consequently, ignore any advantage or disadvantage which may result from the storage and draught of the Morris canal works.

Water-supply.—The population of this water-shed is 71 to the square mile. The percentage of forested area is 39. The portion of the water-shed lying above Hackettstown is a desirable source of water-supply, and we may even include all above New Hampton. At this point the waters could be drawn off at an elevation of 400 feet above tide-water. A tunnel about one and one-half miles long would carry them to the eastern slope of the Highlands, whence they could be conducted to the populous districts eastward.

The drainage above embraces 122.4 square miles, 25.4 square miles of which is already provided with storage in Lake Hopatcong, leaving 97 square miles to be provided with 7 inches storage, or 11,799,000,000 gallons in all. Sites for storage may be found along the main stream and in the valley of Lubber's run. With this storage, the water-shed would supply 81,600,000 gallons daily. Without storage, the stream will supply 9,914,400 gallons daily at New Hampton at all times.

Above Hackettstown, the drainage area is 74.6 square miles. Seven inches storage will require 5,985,000,000 gallons in addition to Lake Hopatcong, and the total supply will then amount to 49,700,000 gallons daily. Without storage, it will not exceed 6,042,000 gallons daily. The elevation of intake of this supply would be 560 feet. Some three miles of tunnel would conduct it to the South Branch of the Raritan, at German Valley, to be combined with a supply from this water-shed for eastern and southern cities.

Lake Hopatcong has a water-shed of 25.4 square miles, lying high in the gneissic Highlands, the elevation of the lake being 926 feet above tide. Its waters are diverted to both the eastern and western slopes of the State to feed the Morris canal, consequently they could very readily be utilized for the supply of eastern cities, preferably by using them to augment the supply from the Rockaway or the Raritan headwaters. The area of the lake is 2,443 acres. It affords considerably more than double the necessary 7 inches of storage. It will therefore furnish a daily supply of 16,900,000 gallons. Forests cover 94 per cent of its water-shed and the resident population is nominal. It has, for some years, been quite a popular summer resort.

Gaugings of the Morris canal during October, 1890, showed a draught of 73.5 cubic feet per second, 55 of which was going eastward and 18.5 westward. The westward flow into the stream was about 36 cubic feet per second. The canal flow below Saxton Falls was 36.4 cubic feet per second, showing further draught from Stanhope and Cranberry reservoir, the canal and river flows being much commingled above this point. At Washington the westward flow was 41.4 cubic feet per second, showing that the leakage was more than made up by further draughts from small streams.

Lubber's run has 24.1 square miles of drainage, 87 per cent. of which is forested, and only 15 inhabitants per square mile. With 7 inches storage it would afford a good supply of 16,000,000 gallons daily, but it can scarcely be of importance excepting as a part of the larger supply at Hackettstown already noticed. The other branches of the Musconetcong are small and unimportant.

Water-power.—As may be seen in our table of net horse-power by water-sheds and by industries, in Appendix I., the Musconetcong is largely utilized for water-power, showing 2,042 net horse-power in use. At Finesville, the water-shed being 155.8 square miles, the available power from the natural flow is 10.75 horse-power per foot of fall. At Warren Paper Mills it is 10.45 per foot fall. The amount actually utilized at the fine mills of the Warren Manufacturing Company is from 11 to 18 horse-power per foot of fall. Our estimate of 10.45 is for continuous power, day and night. It should be noted that the succession of mill-ponds up stream serve to concentrate the power into working hours, thereby making the 18 horse-power per foot fall available for 12 or 14 hours per day. The Warren Paper Mills have 48 and 27 feet fall, respectively. Of the 130 feet fall from Bloomsbury to the mouth of the river at Riegelsville, 126 feet, or practically all, is thoroughly improved excepting at Jacoby's mill seat, where 9 feet fall once in use is now idle.

At New Hampton, we estimate the available power at 8.44 horse-power per foot fall. This makes it about 9 horse-power at Asbury and 10 horse-power at Bloomsbury for 24 hours daily. The amount improved is 9.5 at New Hampton, 11 at Asbury and 18 at Bloomsbury. This is successfully used for 12 to 14 hours daily. About 40 feet fall is unimproved between Bloomsbury and Asbury, good for 400 horse-power, and conditions are favorable for its development near Bloomsbury. Between Asbury and New Hampton, 20 feet fall is unimproved. The valley is flatter here than at the lower site and conditions less favorable for utilization.

At Hackettstown, we make the available power 5.15 horse-power per foot fall. About 9 horse-power per foot fall is utilized at Stephensburg and Hackettstown. Of 70 feet fall between Stephensburg and New Hampton, 26 is improved, but the remainder is scarcely available for new sites, although some of the old ones might have their fall increased considerably. Of 100 feet fall between Stephensburg and Hackettstown, 38 is utilized. Just above Stephensburg, about 30 feet of the remainder could be developed.

It will be noted that the power actually in use on the Musconetcong ranges closely to 1.8 times our estimated available power, being generally concentrated into working hours by holding back in the mill-ponds.

WALLKILL.

This stream drains the northeastern portion of the Kittatinny valley for a distance of about 15 miles from the New York line, and also a part of the northwest margin of the Highlands. Its source is in Sparta mountain, about 3 miles east of Andover and 21 miles from the point where it leaves the State. The lower 10 miles of its course is through very flat meadows, the head of the great area of flats known as the drowned-lands, in New York. The water-shed is a complex one and will be best understood by reference to the topographical maps of the State. Above Franklin Furnace, it is essentially a highland stream. This portion and the various branches of the Papakating have the flow given in Table No. 51, but for the lower part of the stream Table No. 52 is probably better adapted. The flood-flows are not high, measurements at Hamburg indicating only 15 cubic feet per second per square mile.

Water-supply.—Most of the Wallkill water-shed is badly adapted to become a source of public water-supply. The portion above Franklin Furnace, however, is unobjectionable. The area of this is 31.3 square miles. It has on it several ponds. Morris pond lies in the Highlands east of Sparta, has an area of 136 acres and a water-shed of 1.5 square miles. It was originally improved to supply power to a forge at Sparta and is controlled for storage to a depth of 10 feet. From its own immediate water-shed it will supply 999,000 gallons daily, but 2.4 square miles additional may easily be made tributary to it and, in fact, has already been partly led into it. This increases the available supply to 2,600,000 gallons daily. It is now proposed to use this as a source for a gravity supply to Newton, and it promises to afford, in all respects, an excellent one. Losee pond is upon the Highlands also, southeast of Franklin Furnace, has an area of 137 acres and is said to have a maximum depth of 10 feet. It was built as a reservoir for power at Franklin Furnace. Still farther northeast on the Highland plateau are Sand and Mud ponds, in Hamburg mountain. The former was used as a reservoir for power at Hardistonville, has an area of 32 acres and may be drawn down about 2 feet. This water-shed above Franklin Furnace would furnish, with 7 inches storage, a supply of 20,800,000 gallons daily. It is inaccessible to probable points of demand.

Water-power.—The lowest point upon the main stream at which power can be developed is at Hamburg. The drainage area above this point is 50 square miles, and we estimate the available horse-power at 3.45 per foot fall. At the well-equipped mill of W. H. Ingersoll, the amount improved is 5 horse-power per foot fall. There is sufficient pondage above to make this amount available during working hours. At the paper mill, there is a site with 24 feet fall not at present in use, where the improved power is 3.25 horse-power per foot fall. Our estimate would make 83 horse-power available here for 24 hours per day. There is also an old forge site not in use which is said to have about 15 feet fall and for which we estimate 51 horse-power available. At Franklin Furnace, we make the available power 2.16 horse-power per foot fall. Between this point and Hamburg 60 feet of fall is unimproved.

On Papakating creek there is no fall available until the water-shed becomes too small to develop any considerable amount of power. Most of the branches are of little importance, but Clove river assumes considerable importance as a power-stream, because of its being in a region otherwise quite bare of water-power. It rises in Kittatinny mountain, and on one of its headwaters, Sand pond, at an elevation of 1,302 feet, has been improved as a reservoir for the mills below. Its area is 65 acres, and it may be drawn down 8.5 feet. It has a drainage area of 0.7 square mile. Measurements of flood-flow from reported high-water marks give 67 cubic feet per second, which is at the rate of 96 cubic feet per second per square mile. Clove river is said to become very muddy in floods, and it undoubtedly has a very heavy flood-flow, although we have no gaugings. The area drained above Deckertown is 20 square miles, and we estimate the available horse-power at 1.38 per foot fall. Mill-owners here claim that they can always obtain power at the rate of .03 horse-power per foot fall per square mile. The power improved ranges from 2.5 to 3 horse-power per foot fall. In all, 259 horse-power is in use in the Clove. The other branches of the Wallkill in New Jersey are mostly of small importance. Wawayanda lake, on one of the tributaries of Pochuck creek, lies at an elevation of 1,152 feet in the Highlands. It is now part of a sportsman's preserve. Its area is 240 acres, and it receives the drainage from 6.5 square miles. This is one of the frequent examples of high development of a small water-shed for use in iron manufacturing. At the outlet there is a stone dam 225 feet long, 13 feet high and 24 feet thick at the top. The lake may be drawn down to a depth of 8 feet, affording about 3.5 inches storage upon its water-shed. On the outlet there was formerly a saw-mill, and a charcoal blast furnace said to have been built in 1845, and purchased in 1857 by the Thomas Iron Company. In this year it was blown out, and has not since been in blast. The saw-mill had 18 feet fall, and the furnace 35 feet fall. With the storage afforded by the lake, a flow of 1.25 inches monthly could be maintained throughout an ordinary dry year, making the power .78 horse-power per foot fall for 24 hours daily, giving 14 horse-power at the saw-mill, and 27.3 horse-power at the furnace. As this could be concentrated into working hours, they, of course, become 28 and 54 horse-power respectively. The pondage was further increased by a large saw-mill pond, 1.5 miles up stream, the dam of which is said to have broken out about 35 years ago. As the outlet of the lake has a fall of 460 feet within a distance of 1.5 miles above where it crosses the State line, it will be seen that it would be possible to develop a large amount of power, upward of 300 horse-power continuous, at a point convenient to stations on the Lehigh and Hudson River railroad. Such a power, although on a small water-shed, would be more reliable than many powers of equal amount on much larger streams with a less amount of fall.

Wawayanda lake, with its present storage, will afford a continuous supply of 2,769,000 gallons daily of water which should be pure and wholesome. It is remote from probable demand at present.

Decker pond is on a small branch of the Wallkill, in Pochuck mountain. It has an area of 76 acres, and may be drawn down 4 feet, having been used for mill-power on its outlet. Roe, or Carpenter's pond is also on Pochuck mountain, has an area of 23 acres, and may be drawn down 2 feet. It affords storage for the mill at Glenwood.

The remaining streams of the Highlands are tributaries of the Passaic and Raritan, and we shall defer their consideration until we take up these water-sheds, as it will be more convenient to have them appear in connection with their respective drainage systems. Like the other streams of their class, however, their flow is that shown in Tables Nos. 51 and 52.

PASSAIC RIVER.

The best understanding of this water shed may be had by reference to the map of the State accompanying this report, or, still better, to the larger topographical atlas.

The Passaic is our most valuable stream from every point of view. By a fortunate coincidence, its headwaters afford our very best gathering-grounds for public water-supply, and at the same time are the most accessible to the points of greatest demand.

The head of tide-water is at Passaic, 13.5 miles above the mouth, on Newark bay. At the foot of Dundee dam, 4 miles above, the stream is 6 feet above mean tide. Just above the head of tide, Saddle river comes in from the northern red sandstone plain, rising in Rockland county, New York, and draining 60.7 square miles, of which 28 per cent. is in forest. Dundee dam raises the river to 27 feet elevation, and at the foot of Passaic falls, 7.25 miles above, it is 40 feet above mean tide. Excepting Saddle river, only a few small branches are received below this point. At the falls the river leaps sheer 70 feet over a reef of trap rock, at a depression in First mountain. From the top of this fall to the foot of the series of falls and rapids known as Little Falls, the rise is 8 feet. Here there is a fall of 40 feet in three-quarters of a mile, over another trap reef. This is the outlet of the Passaic valley proper, a flat-bottomed valley between the First and Second mountains and the southeastern foot of the

ABOVE PASSAIC FALLS.

GREAT PIECE MEADOWS ON THE PASSAIC.

Highlands, 8 to 12 miles wide and 32 miles long. This valley is covered with masses of glacial drift at various points, and has large areas of flat meadow. Three miles above Little Falls, and at about the same elevation with the head of the falls, the slope of the stream being very gentle, the Pompton river comes in from the north, being formed, as we have already seen in the study of those streams, by the confluence of the Ramapo, Wanaque and Pequannock at Pompton, 6 miles above the confluence with the Passaic. In these 6 miles the Pompton has a total fall of 10 feet.

Just above, on the main stream, lie the Great Piece meadows, through which the Passaic flows in a tortuous channel, spreading its waters, in time of flood, wide over the area, to stand for days and weeks until they can find an outlet at Little Falls, through the restricted passageway which is now being deepened and improved for the better drainage of this valley From the mouth of the Pompton to where the Rockaway and Whippany are received from the west, 12.5 miles above, the fall is only 3 feet. The Whippany also has great meadows just above its mouth, over which its waters spread in floods. For 9 miles above the mouth of the Rockaway the Passaic has a fall of 4 feet; 5.5 miles above Lower Chatham bridge has a fall of 36 feet; about 6.5 feet per mile. Above this the stream has a drainage area of 100 square miles, most of which is very flat, although the headwaters are in the Highlands at Mendham, 23.5 miles above Chatham, by the stream. The total length of the stream which bears the name Passaic, from Mendham to the mouth, is 83.5 miles, measured by the stream. From source to mouth, in a direct line, is only 26 miles.

The area of the entire water-shed is 949.1 square miles; of this, 510 square miles is on the Archean Highlands; the remaining 262 square miles above Little Falls is in the Central Passaic valley, on the red sandstone, and the rest of the water-shed on the trap ridges and the lower eastern red sandstone plain.

We have, by the courtesy of several users of water-power, been able to obtain measurements of flow covering a period of 17 years and a very wide range of rainfall conditions, from 70.88 to 37.03 inches annually. These gaugings were at Little Falls and points below and have been carefully reduced, compared and adjusted, two series being for several years contemporaneous. The results we have much confidence in. They are consistent and bear the test of close analysis as well as any series of gaugings we have. They have already been printed in the collection of long-series gaugings, on which we base our formulæ of flow:

NUMBER OF DAYS PASSAIC STOOD AT GIVEN STAGES DURING SEVENTEEN YEARS (6,209 DAYS).

	Above.	Above.	Above.	Above.	Above.	Above.	Below.
Flow in inches on water-shed in twenty-four hours..............	.125	.100	.075	.050	.025	.015	.015
Flow in inches per month.........	3.81	3.05	2.28	1.52	0.76	0.46	0.46
Flow in cubic feet per second per square mile......................	3.35	2.69	2.02	1.34	.67	.40	.40
1877....................................	62	93	122	152	224	272	93
1878....................................	56	94	114	163	251	306	59
1879....................................	32	58	89	123	191	263	102
1880....................................	3	48	90	120	152	192	175
1881....................................	47	56	73	91	167	223	142
1882....................................	53	61	80	151	244	293	72
1883....................................	23	55	77	128	215	276	89
1884....................................	64	96	126	179	233	269	97
1885....................................	49	74	106	155	236	259	106
1886....................................	51	70	90	150	222	258	107
1887....................................	57	86	131	178	256	299	66
1888....................................	91	117	172	220	256	271	95
1889....................................	130	165	213	295	349	364	1
1890....................................	34	66	124	229	322	355	10
1891....................................	66	89	115	149	189	234	131
1892....................................	27	44	67	119	218	255	111
1893....................................	84	144	175	200	269	317	48
Total..............................	929	1,416	1,964	2,802	3,994	4,706	1,504
Average	54	83	116	165	235	277	88

The flow was above 3.65 cubic feet per second per square mile an average of 47 days yearly; above 4.86 cubic feet 29 days yearly; above 9.72 cubic feet 4.3 days yearly, and above 14.6 cubic feet per second per square mile only 8 days in the whole period. This table makes it appear that our estimated available power, as we compute it, is really available an average of 9 months in the year.

FLOODS ON THE PASSAIC AT DUNDEE DURING SEVENTEEN YEARS, IN THE ORDER OF MAXIMUM FLOW.

Area of water-shed, 822.7 square miles.

DATE.	Maximum flow, cubic feet per second.	TIME FROM BEGINNING OF RISE TO		TOTAL FLOW IN	
		Maximum.	End.	Million cubic feet.	Inches on Water-shed.
September 25th, 1882	18,265	66 hours.	8 days.	7,101	3.71
December 12th, 1878	16,592	60 “	8 “	6,878	3.47
February 14th, 1886.........	12,452	60 “	8 “	5,729	3.00
January 3d, 1888.............	11,880	68 “	8 “	5,295	2.77
January 24th, 1891..........	11,701	60 “	8 “	4,902	2.56
March 14th, 1893	11,245	69 “	9 “	6,590	3.56
May 6th, 1893..................	11,155	72 “	8 “	5,285	2.77
September 21st, 1888........	11,126	72 “	8 “	5,532	2.89
April 29th, 1889	10,967	66 “	8 “	5,020	2.63
March 29th, 1877	10,781	60 “	9 “	5,594	2.93
April 8th, 1886	10,425	55 “	8 “	4,850	2.54
March 3d, 1882................	9,800	48 “	7 “	4,106	2.15
November 10th, 1877........	9,727	120 “	10 “	5,418	2.84
November 29th, 1889........	9,540	72 “	8 “	4,756	2.49
March 23d, 1888..............	9,015	48 “	8 “	4,432	2.32
December 19th, 1888.........	8,917	56 “	6 “	3,578	1.87
August 3d, 1889...............	8,825	66 “	8 “	4,508	2.36
April 8th, 1888................	8,777	....	....	....	....
February 20th, 1884.........	8,394	....	....	....	....
February 24th, 1878.........	8,375	60 “	7 “	3,789	1.98
September 19th, 1889........	8,331	54 “	8 “	....	....
January 14th, 1891...........	8,226	....	....	....	....
January 13th, 1893...........	8,160	72 “	9 “	5,443	2.85
April 20th, 1879	8,052	66 “	7 “	3,836	2.01
March 12th, 1881	8,019	....	....	....	....

Of the above floods those which lasted more than eight days were complicated by two or more storms. The others are the result of a single heavy storm. The end of the flood was taken to be the subsidence of the stream within its banks, corresponding to a flow of about 4,000 cubic feet per second. The total volume of flow in cubic feet is about 6 per cent. less than above at Little Falls. The maximum flow is no less. In the great flood of 1882 it appears to have been 19,060 cubic feet per second, or somewhat greater than above.

A study of flood-flows of other streams of the same size shows the effect of the great reservoirs of flat land in the central valley, and the throttling down of these Passaic floods by the restricted outlet at Little Falls. The Raritan in the great flood of 1882 reached a maximum of 52,000 cubic feet per second in about 24 hours, and in 64 hours, or before the Passaic had reached its maximum, it had discharged the whole flood, whereas the Passaic required 8 days for such discharge. The area of water-shed above the dam below Bound Brook, where these Raritan gaugings were made, is 879 square miles against 822 square miles for the Passaic at Dundee. Gaugings of the headwaters of the Passaic show that they too discharged their full flood-flow into the central valley in 64 hours. After this time they continued to flow about bank full, or a little less, and their discharge into the central valley from this time until the Passaic flood was over at Dundee, I estimate to have been at above 3,000 cubic feet per second for 8 days, less 64 hours flood, less 1 day required for their water to reach Dundee. They consequently added to the Passaic flow at Dundee, by their ordinary flow during the subsidence of the main stream, 1,123 million cubic feet, or 0.58 inches on the water-shed. Deducting this from the 3.71 inches above given leaves 3.13 inches on the water-shed as the actual flood-flow of the Passaic. The total flood-flow of the Raritan discharged in 64 hours equaled 3.36 inches upon the water-shed. This shows us that, while the maximum flow and the time of delivery varied greatly, the total flow was about the same.

The flood of 1882 was probably the highest of this century, consequently more flood-marks are preserved, and a better recollection prevails of this than of other floods. By inquiry and comparison of data of other floods which I have obtained, I have been able to construct a fairly-accurate history of this flood. The waters began to rise at Dundee and Little Falls in the afternoon of the 22d, and rose steadily for 33 hours, when they reached 16,049 cubic feet per second. They then fell off for about 10 hours to 13,000 cubic feet per second, and then rose until they reached a maximum, 66 hours after the beginning of the rise, of 18,265 cubic feet per second at Dundee and 19,100 cubic feet at Little Falls. The upper branches appear to have discharged their flood-waters into the central valley within 72 hours, and to have subsided within their banks. They reached their maximum discharge in from 20 to 40 hours after the beginning of the rise on the Passaic. In the following tables the maximum flows are obtained from well-defined flood-marks at dams. The total discharge is estimated to be 3.13 inches on the shed, as already determined.

Plate 7.

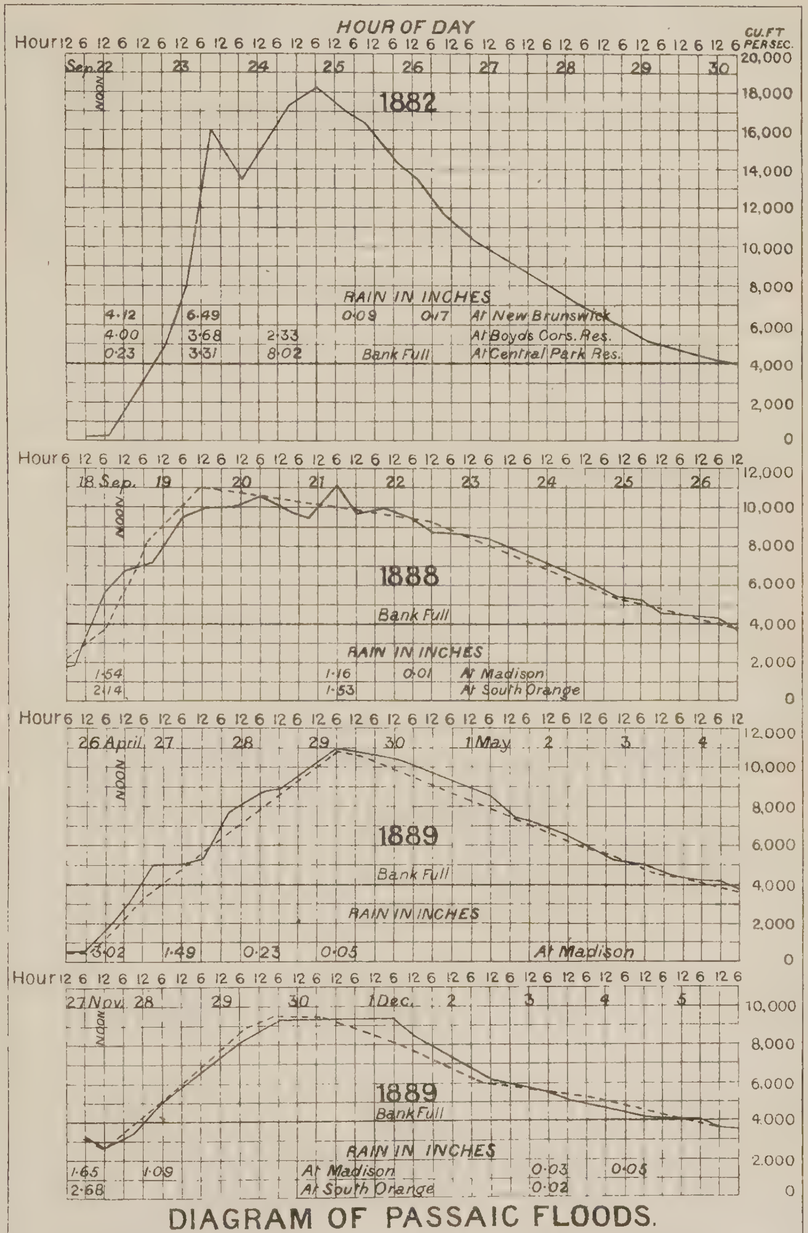


DIAGRAM OF PASSAIC FLOODS.

Full Line-Height at Dundee. Broken Line-Height at Little Falls.

JULIUS BIEN & CO N.Y.
J. R. Prince Del.

FLOOD DISCHARGE INTO CENTRAL PASSAIC VALLEY.

September, 1882. Time, 72 hours from rise.

Stream.	Area.	Maximum Flow, Cubic Feet per Second.	Total Discharge. Cubic Feet.
Ramapo	160	10,540	1,163,000,000
Wanaque	101	6,666	734,000,000
Pequannock	85	4,460	618,000,000
Pompton	34	....	247,000,000
Rockaway	118	4,800	858,000,000
Whippany	25	....	182,000,000
Upper Passaic	100	....	727,000,000
Central Valley	150	....	1,091,000,000
Totals	773	....	5,620,000,000

The Pompton reached its maximum flow at Two Bridges in 30 hours, and I estimate that this was about 16,000 cubic feet per second. The Ramapo maximum was reached in 24 hours, and the Wanaque at about the same time, the Pequannock being somewhat earlier. The Passaic discharged in 72 hours at Little Falls 2,572,000,000 cubic feet, so that there must have accumulated in the flats 3,048,000,000 cubic feet. The rise at Two Bridges was 14.6 feet above the level of the dam. If we consider the flood-lake above this point level, it would have a capacity of 2,294,000,000 cubic feet. On the other hand, if we join all the high-water marks in the valley, we shall have a sloping surface and a capacity of 4,000,000,000 cubic feet. Neither of these gives the actual volume of accumulated waters, since highest water did not occur at all points simultaneously. The true amount was somewhere between the two, and undoubtedly not far from what we determined above, or 3,048,000,000 cubic feet. This accumulation was discharged during the remaining five days of the flood. The first maximum of the flood at Dundee was undoubtedly from the Pompton. Somewhat before the Rockaway at Boonton or the Upper Passaic at Chatham had reached their maximum discharge, the Pompton reached its maximum at Two Bridges. This maximum cannot be delivered by the Passaic until it has reached a height of 13 feet at Two Bridges, consequently the Great Piece must be filled up to this level. The waters of the Pompton rushed back up the Passaic toward Pine Brook to restore the equilibrium, and when this was accomplished the Passaic at Little Falls reached its first maximum. It then began to fall slightly until the settling down of the waters from the upper meadows raised the head at Two Bridges, and consequent discharge at Little Falls to its maximum, some 33 hours after the first rush from the Pompton had culminated. The flow then steadily receded for 5 days until the accumulated waters had been withdrawn off the flats. A diagram of this and other high floods is shown in Plate VII.

Dry-season flow.—The lowest monthly flow shown by our record is in October, 1881, amounting to 0.22 inch on the water-shed.

On October 10th, 1878, Messrs. Croes and Howell gauged the flow at Paterson during a very low stage of the river. They found it to be 195 cubic feet per second, and remark that it did not vary appreciably from this for ten or twelve days. (Newark Aqueduct Board, Report on Additional Water-Supply, 1879, J. J. R. Croes and George W. Howell, page 35.) This is at the rate of 0.28 inch on the watershed for the month.

In September, 1883, Mr. Lebbeus B. Ward found the flow at Paterson to be at the rate of 150 cubic feet per second, which is at the rate of 0.21 inch per month.

The last appears to be the very lowest point reached by the stream under natural conditions for so long as three consecutive weeks.

In September, 1894, our observations show a minimum flow at Dundee for about a fortnight at the average rate of 138 cubic feet per second. About 8 per cent. of the flow had at this time been diverted for the supply of the city of Newark, consequently this gives the same rate as that observed by Mr. Ward in 1883, which may be regarded as the minimum flow under natural conditions. It is at the rate of 0.19 cubic foot per second per square mile of water-shed.

Table No. 53 has been computed to show the flow of the Passaic for typical years.

TABLE No. 53.

Estimated Flow of Passaic River.*

AVERAGE YEAR.

	December.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	Year.
Inches of rainfall	3.65	3.55	3.38	3.64	3.55	3.96	3.96	4.14	4.50	3.64	3.38	3.65	45.00
Inches flowing off	2.87	2.92	2.74	2.80	2.55	1.65	1.08	.58	.49	.51	.80	2.31	21.30
Flow in thousand gallons daily per square mile	1,610	1,635	1,640	1,570	1,430	925	605	325	274	285	448	1,290	1,015
Horse-power on one foot of fall per square mile	.302	.288	.289	.276	.260	.163	.110	.057	.048	.052	.079	.236	.179
ORDINARY DRY YEAR.													
Inches of rainfall	3.95	4.04	1.67	2.95	2.60	3.36	3.75	4.47	3.93	.99	2 09	2.22	36.00
Inches flowing off	3.14	3.37	1.20	2.17	1.75	1.24	.80	.53	.45	.32	.32	.41	15.70
Flow in thousand gallons daily per square mile	1,760	1,885	717	1,218	1,015	695	464	297	252	185	179	237	747
Horse-power on one foot of fall per square mile	.310	.332	.126	.214	.178	.122	.082	.052	.044	.033	.032	.042	.132
DRIEST YEAR.													
Inches of rainfall	4.05	3.66	4.76	383	.61	2.71	3.87	.96	1.18	.94	3.04	2.02	31.63
Inches flowing off	3.22	3.02	3.98	2.97	1.03	.53	.47	.37	.25	.24	.23	.22	15.53
Flow in thousand gallons daily per square mile	1,800	1,690	2,380	1,660	597	297	272	207	140	139	129	127	740
Horse-power on one foot of fall per square mile	.317	.298	.419	.293	.105	.052	.048	.036	.025	.024	.023	.022	.131
Continued.													
Inches of rainfall	2.63	4.57	4.22	3.57	2 12	5.06	1.90	1.37	6.40	12.09	1.32	.99	46.24
Inches flowing off	.25	.59	3.50	2.73	1.56	1.66	.80	.31	.30	5.69	1.34	.62	19.35

* For Highland tributaries use Table No. 51.

Storage needed to utilize 14 inches per annum, or 666,094 gallons daily per square mile, is 7.52 inches, or 130,331,520 gallons per square mile. In the driest period such reservoirs would not be full from April to September, a period of 18 months. For 9 months of an ordinary dry year, and about 75 per cent. of the whole time, .044 horse-power will be available for one foot of fall for each square mile of water-shed.

It will be noticed that we estimate a smaller amount flowing off from the Passaic water-shed than from the Highland streams. The rainfall is about 1 inch greater in an average year, and about 0.8 of an inch greater in an ordinary dry year than upon the Highland and Kittatinny valley region. The flow from ground-water for a given depletion is also greater, as will be seen by reference to the diagrams of ground-flow. Both of these are offset, however, by the increased evaporation, which we take to be 11.5 per cent. over that of the Highland and Kittatinny region. The average elevation of the Highlands is about 700 feet greater than that of the Central Passaic valley and northern red sandstone plain. This difference of elevation would be equal to over 2 degrees difference in mean temperature, allowing 300 feet elevation to 1 degree decrease in the temperature. We are of the opinion that our estimation of an extremely dry period, as dry as that shown by the Philadelphia record, is a little too severe for a water-shed of 800 square miles in extent. Such extreme droughts do not seem to extend over so large an area, and it will be noticed by reference to the table of gaugings of the Passaic that the rainfall and flow were very considerably larger during 1881 and 1882 than the above estimate shows. Our assumed driest period is not too severe, however, for smaller portions of the water-shed. If it errs when applied to the main stream, the error will be on the safe side, and no great harm can result. It may be remarked that so severe a dry period as this will be modified during December and the later winter months by the freezing up of the ground, and the flowing over the surface of a portion of the rainfall to the stream. The ground will, consequently, not be entirely filled with water until a thaw occurs, but then replenishment must take place and the flow will be decreased. It will be found that the actual flow during November and the winter months will not usually be less than one-half an inch upon the water-shed in a climate as cold as that of the Passaic. There is no way to compute the effect of freezing, however, and if any allowance is made for it, it must be a matter of good judgment. We believe that it will be safe to depend upon a total annual yield of 14 inches from this water-shed, but it should be remembered that it is extremely probable that this will result in long periods of low reservoirs. It is apparent from the table that a reduction to 12 inches per annum will not sensibly diminish the length of this period of low reservoirs. To utilize 12 inches we shall need 5.85 inches of storage.

Water-supply.—It will be seen from our table of public water-supply systems of the State, in a later chapter, that the Passaic now furnishes a large amount of water to our cities. Jersey City pumps over 22,000,000 gallons daily from the river at Belleville, but our later remarks upon the subject of river pollution show why no part of the river below the falls at Paterson can be seriously considered for purposes of water-supply. The next point up stream where water is drawn for city use is above the falls at Paterson. Paterson and Passaic are supplied from this point by pumping. The drainage area above the falls is 797 square miles. The river will supply at this point, without storage, 87,569,856 gallons daily. It must be noted that 8 per cent. of the area above the falls has already been diverted to supply the city of Newark, and another considerable area is likely to be shortly set apart to supply Jersey City. The available supply at the falls will be correspondingly decreased. Our estimate above is for the total natural flow of the stream. The agricultural character of the central valley, and its large and increasing population forbid that we should consider this supply at the falls as altogether desirable for the future, although at present it is all that can be desired. Above Little Falls the river receives the drainage of 773 square miles, and will supply, without storage, 84,661,632 gallons daily. With 7.5 inches storage upon the water-shed, 515,000,000 gallons daily will be available. The elevation of the river at this point is 159 feet. Our remarks as to the desirability of the supply at Paterson apply equally well to this.

Pompton river, at Two Bridges, affords the most desirable supply obtainable at any point below the Highlands. The drainage area is 379.9 square miles. This is largely a Highland water-shed, but Table No. 53 will best apply. We estimate the minimum flow to be at the rate of 0.15 of a cubic foot per second per square mile, so that 36,837,504 gallons daily may be had here without storage, the elevation being 170 feet. To utilize 14 inches annually from this water-shed there should be storage equal to 7.25 inches, and the resulting supply would be 253,000,000 gallons daily.

This storage may be obtained by means of a dam at Mountain View, 2,200 feet long and 57 feet high, for which nature has provided an excellent site. Such a dam will flood Pompton Plains, including an area of 18.07 square miles, to an elevation of 220 feet, and a draft of ten feet upon this reservoir will afford the necessary storage. While this appears to be a work of unnecessarily large magnitude at first sight, it has many excellent points, and for the full utilization of the available gathering-grounds of the Passaic water-shed it has no equal. It is, in fact, the only way in which the waters of the Wanaque and Ramapo can be collected by works entirely confined to the State of New Jersey. It would be possible to ultimately add to the area tributary to this reservoir the water-shed of the Rockaway, above Boonton, 118 square miles in extent, which would make the total available supply 332,000,000 gallons daily, all collected in one reservoir, which would, from its magnitude, partake of the character of a natural lake, and which will be more easily guarded from pollution than a large number of reservoirs such as would otherwise be necessary to accomplish the same result.

The upper Passaic, above Two Bridges, is not a desirable stream as a source of water-supply. Too large a proportion of its area lies upon the flat central valley. There are large areas of wet land, and the stream becomes quite muddy at times, and a general examination of the gathering-grounds would result in its condemnation, although the analyses which we have indicate a fairly good water at present. Of course these remarks do not apply at all to the Rockaway and other Highland branches. Upon this part of the stream floods rise slowly, cover a very large area of flats, and remain high seven or eight days.

The Passaic, above Chatham, drains 99.8 square miles. Table No. 53 applies to the flow of this water-shed. The water is muddy and inferior in quality, and the opportunities for storage for water-supply purposes are not at all good. Floods rise more slowly than upon the other branches of the Passaic, and remain high three or four days. The maximum flow probably does not exceed 40 cubic feet per second per square mile. From the dry-season run of mill-wheels at Chatham we estimate the minimum flow to be 0.14 of a cubic foot per second per square mile. At Millington we find in the same way 0.13 of a second per square mile. These figures agree closely with minimum gaugings on the Ramapo and Pequannock. At Chatham 8,724,672 gallons daily may be obtained without storage. With 7.5 inches storage, 66,500,000 gallons daily may be obtained. The elevation is 200 feet. Above Franklin, which is at the crossing of the Morristown and Bernardville highway, the upper Passaic becomes purely a Highland stream, to which Table No. 51 applies. It is an excellent gathering-ground, but drains only 9.2 square miles. The elevation is 270 feet, or could be made 320 feet with little loss of area. The supply, with storage amounting to 1,119,000,000 gallons, will be 6,100,000 gallons daily.

The most desirable water-supply streams of the Passaic water-shed are the Ramapo, Wanaque, Pequannock and Rockaway, which we will consider by themselves a little later.

Water-power.—The fact must not be lost sight of, in considering the Passaic as a water-supply stream, that the diversion of the Highland branches for the supply of the northeastern cities of the State has already been begun, and is likely to continue until all have been appropriated. When this is accomplished, the available power of the lower stream will be reduced to three-eighths of our estimate, which is, of course, for the total natural flow. If this diversion is not made good by storage upon the lower portions of the Passaic, the stream will rapidly lose its prominence as a source of water-power. These facts, however, do not make it any the less important that we should have a correct estimate of the available power of the stream. From Little Falls to tide the total fall is 159 feet, and of this, 102 feet is improved. Practically the only available fall unimproved is some 25 feet at Little Falls.

The Dundee Water Power and Land Company has developed a large water-power just above the head of tide at Dundee. Their dam is a substantial stone structure 450 feet long, and the raceway is nearly two miles in length. The pond has an area of 224 acres, and retains the entire flow of the stream during dry seasons, so as to concentrate it into working hours. The fall varies with the state of the tide from 20 to 24 feet, the average being about 22 feet. Power is leased to the mill-owner by the mill-power, defined to be 8.5 cubic feet per second during 12 hours in the day, the price of a mill-power being stated to be $700 per annum, or about $33.33 per gross horsepower. From a return made in 1890, seven establishments were renting power, and the aggregate amounted to 1,764 gross horsepower. Table No. 53 makes the power available for 9 months of an ordinary dry year 36.18 horse-power per foot fall. According to the above, 80 horse-power per foot fall is improved and used during 10 hours daily, our previous figures being, of course, for continuous power.

The next power above is at Passaic falls, and was developed by the Society for the Establishment of Useful Manufactures, chartered in 1791. This is one of the earliest of the large water-powers of the United States. The dam is of stone above the head of the falls, and affords sufficient pondage to concentrate the entire dry-season flow into working hours. The water is taken off by a raceway, and is used on 3 falls of 22 feet each, as shown in the accompanying plan. Water-power is leased at the rate of $750 per square foot under a head of 3 feet. This amounts to about 8.5 cubic feet per second, and 21.25 gross horse-power on a fall of 22 feet, making the price per gross horse-power about $36 per annum. This is for 12 hours daily, and during the dry season the water is shut off from the mills at night. This price does not include any guarantee that the water will be available at all times. It will be noted that the 2,350 horse-power leased amounts to 35.6 horse-power per foot fall. By our table, 35.07 horse-power per foot fall will be available for continuous power. The lowest flow of the stream is less than 17 horse-power per foot fall, so that it will be seen that at times there is a shortage, and most of the mills are provided with steam. This power has been largely instrumental in building up the city of Paterson.

At Little Falls we estimate the available horse-power at 34.01 per foot fall. We find 31.5 horse-power improved. Only 14 feet fall is in use here, whereas the total fall amounts to about 40 feet. Our estimate on the total fall gives 1,360 available horse-power. Pondage enough to hold back the extreme dry-season flow would make this always available during working hours. Above this point there is very little fall to the stream until we reach Chatham. At this point we estimate 4.4 horse-power per foot fall to be available. We find from 6 to 10 horse-power per foot fall improved, this amount being secured by pondage so as to be available during working hours for nine months of the ordinary dry year.

Minor branches.—The smaller branches of the main Passaic are largely utilized for power. Second river drains 17.2 square miles, the water-shed being very populous. The improved power ranges from 2 to 10 horse-power per foot fall. We find that at Belleville 0.76 horse-power per foot fall is available continuously. The pondage is sufficient to make this 1.5 horse-power during working hours. Yantecaw, or Third river, is also largely in use. At the last mill we estimate 0.62 horse-power per foot fall available. The pondage

THE RACEWAYS AT PATERSON.

here is very large, there being a succession of considerable mill-ponds. Peckman's brook drains 10.5 square miles, so that near the mouth 4.6 horse-power per foot fall is available, and at the railroad crossing, near Cedar Grove, 3.70 horse-power. We find from 1.7 to 3 horse-power per foot fall improved, but at one set of mills it runs as high as 7 horse-power.

Between Cedar Grove and the mouth of the brook 123 feet out of a total of 150 feet of fall is improved.

The remainder of these minor branches of the Passaic are not of sufficient importance to call for extended notice.

Drainage works.—The lands which we have alluded to as overflowed by the accumulation of the flood of 1882 above Little Falls embrace a large area of wet meadows subject to frequent overflow. The result is the loss of much land which would otherwise be valuable, and the prevalence of malarial disease. When the river is discharging at Little Falls 4,000 cubic feet per second, it is bank full at Two Bridges, and beginning to overflow the meadows. Our table shows that it was above this stage 485 days in 17 years, or an average of one month in each year. The following table gives the area of the land subject to overflow, and which is too wet for cultivation, and also the water-shed, the flow from which causes the trouble:

WATER-SHEDS AND WET LANDS AREAS, PASSAIC.

	Water-shed. Square Miles.	Wet Lands. Acres.
Passaic, above Millington	53.6	10,400
Passaic, Millington to Chatham	46.2	4,354
Passaic, Chatham to Pine Brook Bridge	46.9	3,117
Whippany—Total	71.1	5,094
This includes Troy and Black Meadows, 4,275; Lee Meadows, 512; Washington Valley Meadows, above Morristown, 307 acres.		
Rockaway—Total	137.2	173
Deepavaal	......	378
Passaic additional, Pine Brook to Two Bridges	12	4,089
Total for South Branch of Passaic	367	27,605
Pompton—Total	379.9	1,140
Passaic additional, Two Bridges to Little Falls	26	563
This includes Preakness Brook Wet Lands, 320 acres.		
Total above Little Falls	772.9	29,608

Of the above area, between Two Bridges and Pine Brook bridge, the larger portion below Horse-Neck bridge is known as the Big Piece meadow, and the smaller portion as the Little Piece. At ordinary stages the elevation of the river at Little Falls is 158 feet. At Two Bridges, 17,000 feet above, it is 160 feet. From this point through the Great and Little Piece to Pine Brook bridge, the distance, following the tortuous channel of the river, is 11 miles, and the elevation at the latter bridge is 163, showing a fall of only a little over 3 inches per mile. At Pine Brook the river overflows its banks when it is discharging over 2,000 cubic feet per second. There is a short cut through a low depression from this point to the river about one mile below Two Bridges, through which the water flows when there is a rise of 4 feet at Pine Brook. By this route the distance is 3.75 miles instead of 12 miles by the natural river channel, and it has been proposed, and, in fact, attempted to divert the stream through this depression, and so increase the fall and shorten the time of floods on the upper meadows. From Pine Brook bridge to Lower Chatham bridge the distance is 10 miles, and the river has a total fall of 4 feet. The Rockaway, which becomes tributary to the Passaic just above Pine Brook, has a fall of 3 feet on its lower two miles, this portion being bordered by meadows, but above this the Rockaway has a considerable fall, and does not seriously overflow its banks. The Whippany flows through Troy meadows, and this and Black meadows have an elevation of about 167 near the mouth of the Whippany, and 174 six miles southwest. It will be seen that throughout this great extent of meadow the fall of the river is very slight, and the channel is so limited that it is over its banks much of the time.

As we have mentioned, drainage works are now under way, having for their object the reclamation of this large area of lands. The first step is the reduction of the trap-reefs at Little Falls, a work which is already accomplished, so that the falls are now entirely obliterated, and the lowering of Beattie's dam at the head of the falls 20 inches. Flood gates are also to be introduced, which are to be opened when the water has reached a height of one foot on the dam, the object being to keep the level of the river as low as possible at this point, and so to hasten the discharge of floods. Owing to the restricted capacity of the channel above Two Bridges, it also must be cleared and enlarged in order to make the work a success. The object of this work is rather to hasten the discharge of floods and shorten the time in which the meadows are flooded and wet than to do away with the overflowing of the meadows entirely. Any attempt to confine the flood-waters wholly to the channel would result in an increase of the maximum flood-flow to about the same rate that we have observed upon the Raritan, or say 50 cubic feet per second per square mile. It will be seen that this would require a channel from Two Bridges to Little Falls having a capacity of 38,650 cubic feet per second, or nearly ten times the present capacity, and the proportionate enlargement of all the channels above flowing through these wet lands. Not only would this be impracticable, but there is a question whether it would even be desirable, as the lands overflowed are very considerably enriched by the sediment. If they can be made sufficiently dry to produce good crops of hay and pasturage, the work will be considered a success.

SADDLE RIVER.

This branch of the Passaic rises in Rockland county, New York, about three miles north of the State line, and flows almost due south for 17 miles, emptying into the Passaic at Passaic City. It drains 60.7 square miles, of which 8 square miles is in the State of New York. Twenty-eight per cent. of this area is in forest, and the population is 122 to the square mile. It is essentially a red sandstone stream, the underlying rock being of the harder class of red sandstone. The western part of the water-shed drained by Hohokus creek is largely drift-covered, but the portion drained by the main stream is comparatively free from sand and gravel. Table No. 53 is adapted to this stream, as it partakes largely of the character of the main Passaic water-shed. Floods are usually one day in rising, remain high about 12 hours and fall on the day following.

Water-supply.—Above 90 feet elevation the main stream drains 21 square miles. This is a very fair gathering-ground for water-supply. The stream carries less sediment than the more southerly red sandstone streams. We estimate that with 7.5 inches storage 14,000,000 gallons daily may be collected. Without storage the stream at this point is good for 2,667,000 gallons daily. Although not quite so desirable as the Highland tributaries of the Passaic, it is convenient to points of demand and may be utilized in the future. The facilities for storage are confined to the main valley, but it would be possible to procure the necessary 7.5 inches here. Referring to our later estimates of the flow of red sandstone streams, there will be seen to be some little doubt whether it is advisable to attempt to collect more than 12 inches annually from this water-shed. We are of the opinion that while 14 inches may be collected, it is not advisable to attempt it, because of the long periods of low reservoirs which must follow. Taking 12 inches of the limit, the available supply above Paramus at 90 feet elevation will be 12,000,000 gallons daily.

Water-power.—Below Paramus to the mouth of the river we find 60.5 feet out of the total of 90 feet fall improved for water-power. It is evident that not many opportunities exist for new development on the stream. We estimate the available horse-power at the mouth at 2.67 per foot fall. Below the junction of Hohokus creek we make it 1.89 horse-power per foot fall. The power improved on this portion of the stream ranges from 6 to 12 horse-power per foot fall. At Paramus we make the available power 0.92 horse-power per foot fall. We find 5 horse-power actually improved. At the village of Saddle River we estimate 0.73 horse-power per foot fall, and find from 4 to 5 horse-power improved. On Hohokus creek, at Hohokus, we estimate the available power at 0.69 horse-power per foot fall, and we find from 5 to 6 horse-power improved. It would be interesting to know what has led to such a large amount of power being improved upon this stream. To a certain extent it is due to the presence of two kinds of mills, such as saw and grist-mills, upon the same fall, and these mills are probably rarely both run at the same time. The development of an amount of power which can only be realized during a very small part of the year is likely to give rise to expectations which are not warranted, and in this way frequently discredits the use of water-power. The estimates which we have given of available horse-power are the amount of power actually available during about nine months of the year. They may be double or even be increased 2.4 times for use during working hours by pondage.

RAMAPO RIVER.

This branch of the Passaic rises in Orange county, New York, near Monroe. It drains 160.7 square miles, of which 112.4 square miles is in New York. About 75 per cent. of the area is in forest, and the population is 58 to the square mile. Most of the course of the stream is in a low valley in the midst, or to the east of the Highlands, which rise from 700 to 1,000 feet above. Tuxedo, Sterling, Mount Basha and several smaller lakes afford a considerable natural storage. Most of these have been improved in the past as reservoirs to furnish power for iron manufacturing, and they may be drawn down to a considerable extent, but are not at present so drawn. At Pompton, 1.5 miles above its confluence with Pompton river, the stream has a natural fall over a reef of trap rock of about 15 feet. This has been increased to 23 feet by a dam, the lake above being 202 acres in extent. From the head of this pond, two miles further up stream, to Suffern, at the New York line 10 5 miles above, the fall is 5.7 feet per mile; thence to Augusta, 9 miles further, it is 18 feet per mile; thence to Turner's, 7 miles above, it is 7 feet per mile. The total length of the stream from its remotest source is 34 miles. There was formerly a large amount of power used on the New York portion of the water-shed for iron furnaces and forges, but very little of this is at present in use.

The maximum flow of the stream at Pompton we have determined from high-water marks to be 66.1 cubic feet per second per square mile. In our table of gaugings we show a minimum flow, October 10th, 1892, at the rate of 0.14 cubic feet per second per square mile. The following table shows the results of simultaneous gaugings at Ramapo, New York, and at Pompton, New Jersey, at the close of an extremely dry period in 1894:

SIMULTANEOUS DRY-SEASON GAUGINGS OF RAMAPO RIVER, AT POMPTON, N. J., DRAINAGE AREA 159.5 SQUARE MILES, AND AT RAMAPO, N. Y., DRAINAGE AREA 86.4 SQUARE MILES.

	AVERAGE FLOW IN CUBIC FEET PER SECOND.	
1894.	At Pompton.	At Ramapo.
September 13th	15.53	16.29
September 14th	15.53	15.13
September 15th	15.53	15.58
September 16th	24.86	13.94
September 17th	38.84	15.08
September 18th	38.84	18.41
September 19th	38.84	....

We are satisfied that from the 13th to the 15th the above flow at Pompton is less than the natural flow of the stream. The water must have been held in some of the intervening mill-ponds, and let down so as to increase the flow from the 16th to the 19th. If we take the six days ending at 6 P. M. on the 18th, at Ramapo, we find the average flow is 15.74 cubic feet per second, or at the rate of 0.182 per square mile. Allowing 12 hours for the water to reach Pompton, and taking the average flow at that place for 6 days ending with 6 A. M. on the 19th, the average flow is 28.41 cubic feet per second, or 0.178 cubic feet per second per square mile. From this it will be seen that the average during 6 days at the two places is almost exactly proportional to the water-shed drained. From the above facts we place the absolute minimum at 0.14 cubic feet per second per square mile. Gaugings were made for two years at the works of the Pompton Steel and Iron Company by the courtesy of the late Mr. James Ludlam, and the results are given in the accompanying table:

FLOW OF RAMAPO RIVER AT POMPTON, NEW JERSEY.

Drainage area, 159.5 square miles.

MONTH.	Rain—Inches.	Flow—Inches.	FLOW IN CUBIC FEET PER SECOND.		
			Greatest.	Least.	Average.
1890.					
February 7th to 28th	4.45	3.29	1,913	277	643
March	6.40	4.85	2,020	277	643
April	2.68	3.05	1,032	231	429
May	4.72	2.75	762	170	377
1890-1.					
June	4.98	1.25	334	55	176
July	6 06	.94	338	40	125
August	4.75	.80	601	41	108
September	4.14	1.51	948	55	209
October	6.95	2.22	839	91	301
November	.77	1.10	320	80	155
December	4.02	1.77	1,583	80	238
January	8.51	6.36	4,552	318	879
February	4.50	5.28	2,130	264	853
March	4.25	5.23	1,686	299	729
April	2.80	2.34	695	143	335
May	2.70	.67	187	41	94
June to May	54.43	29.47			

FLOW OF RAMAPO RIVER AT POMPTON, NEW JERSEY.—Continued.

Drainage area, 159.5 square miles.

MONTH.	Rain—Inches.	Flow—Inches.	FLOW IN CUBIC FEET PER SECOND.		
			Greatest.	Least.	Average.
1891–2.					
June	2.13	.37	79	33	52
July	4.88	.31	70	22	44
August	5.54	.96	536	33	135
September	2.28	.67	318	40	94
October	2 39	.30	53	40	42
November	2.93	1.47	601	33	207
December	4.77	2.78	1,175	104	391
January	5.65	5.65	1,949	267	794
February	1.34	1.19	267	123	167
March	3.65	2.30	662	147	323
April	1.73	1.33	293	117	188
May	4.66	1.83	748	91	258
June to May	41.95	19.16	....	....	....
1892.					
June	4.07	2.00	1,095	45	281
July	3.37	....	....	....	....
August	4.36	....	....	....	....
September	1.97	....	....	....	....
October	.68	Gaugings October 10th, 22.5 cubic feet per second.			

We have already shown in Table No. 41 that the evaporation indicated by the above gaugings averages about 3 per cent. in excess of that shown by the Passaic formula. On the basis of temperature the evaporation from the Ramapo shed should be about 5 per cent. less than that shown by the Passaic. We are inclined to attribute a portion of the loss shown by the gaugings to leakage at the point of gauging. For safety, therefore, we consider it best to apply Table No. 53 to the Ramapo. We believe its actual flow lies between that of Table No. 53 and Table No. 51, but the former table will give safe results, although possibly a little within the truth. Table No. 51 is best for dry-month flow.

Water-supply.—The Ramapo is an admirable gathering ground for public water-supply. The only points which at present threaten pollution are Suffern, N. Y., a growing village, and Tuxedo, where a small sewer is now discharging into the stream. Naturally the water-shed is all that can be desired. The yield, without storage at Pompton, will be 14,541,120 gallons daily. At Pompton Falls, where the present dam of the Pompton Steel Works is located, there is an admirable site for a high masonry dam on a rock foundation. If raised ten feet higher than the present level of the lake, storage to the amount of 1,065,000,000 gallons, or 0.38 inches on the water-shed, will be afforded. This will maintain the supply at 0.26 inches monthly upon the water-shed, giving 23,680,000 gallons daily. With a total storage equal to 7 inches on the water-shed, the available supply at Pompton will be 119,600,000 gallons daily. In order to obtain this amount of storage it will be necessary to build a number of reservoirs on the New York portion of the water-shed. The following table shows the possible sites for storage, and also gives the area of the various existing ponds which we have referred to. In our remarks upon Pompton river, we have explained the only practicable way in which all this water can be collected by works confined within the State of New Jersey:

POSSIBLE RESERVOIRS ON RAMAPO WATER-SHED.

The total tributary water-shed is given in the seventh column.

RESERVOIR.	STREAM.	STATE.	ELEVATION.		Surface area—acres.	Water-shed—square miles.	Storage needed—million gallons.	Reservoir capacity—million gallons.
			High water.	Low water.				
Suffern	Main	New York and New Jersey.	300′	280′	2,200	134.50	16,371	10,898
Mahwah	Mahwah	New York	350′	320′	1,038	19.50	2,371	6,906
Mechanicsville	Mahwah	New York	390′	360′	675	10.15	1,234	1,265
Ramapo 1	Main	New York	350′	320′	547	90.90	11,057	3,485
Ramapo 2	Main	New York	350′	320′	299	86.40	10,510	1,441
Southfield	Main	New York	500′	460′	626	54.08	6,579	4,050
Greenwood	Main	New York	530′	520′	502	24.84	3,021	1,280
Stony Brook	Stony Brook	New York	460′	380′	255	17.96	2,189	2,806
Echo Lake	Otter Creek	New York	750′	710′	86	4.71	572	676
Cranberry Lake	Otter Creek	New York	1 013′	1,009′	62	.45	55	61
Slaughter Pond	Otter Creek	New York	1,054′	1,052′	120	.62	76	78
Round Pond	Near Monroe	New York	664′	661′	85	.70	85	88
Mt. Basha Lake	Mt. Basha Creek	New York	853′	849′	307	2.98	365	399
Townsend	Mt. Basha Creek	New York	700′	680′	150	4.70	572	590
Indian	Indian Kill	New York	700′	660′	135	3.90	474	567
Tuxedo Lake	Tuxedo Creek	New York	557′	551′	291	3.74	458	475
Negro Pond		New York and New Jersey.	623′	618′	70	.87	106	114

Water-power.—We estimate the available power at Pompton to be 7.04 horse-power per foot fall. Pompton lake concentrates the flow so that during working hours, or 10 hours per day, 2.4 times the minimum flow is always available. The minimum flow being 22.5 cubic feet per second, we find that there would always be 6.14 horse-power per foot fall available, or taking 22 feet as the available head, 132 horse-power will be the minimum. Our table in the appendix gives 160 gross horse-power on 20 feet fall, or 8 horse-power per foot fall, this being the amount reported as used by the mills. We find that wheels are in place having a total of 355 net or about 522 gross horse-power, or 26 horse-power per foot fall. Gaugings of the raceway show 214 gross horse-power actually in use with the mill working in its usual way, and this amount of power appears to be successfully used, being about 10.7 horse-power per foot fall. At Oakland 11 horse-power per foot fall is improved with little pondage. These two are the only water-powers on the Ramapo in New Jersey. Sixty feet fall is unimproved between the State line and Oakland.

WANAQUE.

This stream strongly resembles the Ramapo in the topography of its water-shed. Table No. 53 may be applied to it with safety, the flow lying somewhere between 53 and 51. The minimum flow per square mile could not be obtained owing to draughts upon storage, but it may be safely taken to be 0.14 cubic feet per second per square mile, or the same as the Ramapo. The flood-flows are also modified by storage, our highest observed maximum being about 45 cubic feet per second per square mile. Under natural conditions, it probably runs as high as the Ramapo.

Greenwood lake and Sterling lake afford a large pondage. The latter is used as a reservoir for power at Sterling furnace, New York. It has an area of 321 acres, a water-shed of 4.69 square miles and is not at present drawn off to any considerable extent. It is a beautiful sheet of water in a wooded district at an elevation of 749 feet. Greenwood lake lies partly in New York and partly in New Jersey and is a well-known summer resort, being highly picturesque. It is at an elevation of 621 feet, has a length of 6 miles and quite a uniform width of five-eighths of a mile. It is a reservoir for the Morris canal, has an area of 1,920 acres, or just 3 square miles, and receives the drainage of 28 square miles. Its storage capacity is said

POMPTON FALLS ON THE RAMAPO.

to be 1,340,000,000 cubic feet (Croes and Howell); the dam is of stone 180 feet long and 14 feet high, the waste-way being 100 feet in length. The lake is said to rise about 1.9 feet above the overflow, indicating a flood-flow of 31 cubic feet per second per square mile, largely reduced from the natural flow by the storage afforded on the area of the lake. The lake can be drawn down 14 feet. The storage is largely in excess of the 7 inches which we have shown to be necessary in order to utilize 14 inches annually. The lake will therefore supply at all times 18,600,000 gallons daily, or about 29 cubic feet per second throughout the year. We have observed 68 cubic feet per second actually being drawn through the gates. This water flows down the length of the Wanaque and is taken into the Pompton feeder of the Morris canal at a point near the junction with the Ramapo. We have observed from 49.5 to 40 cubic feet per second being taken into the feeder at this point, and from information and gaugings we estimate the average yearly draft at 38 cubic feet per second, ranging from 30 to 50 cubic feet.

We estimate that Sterling lake, if raised so as to afford 7 inches storage upon its water-shed, will supply 3,140,000 gallons daily. Table No. 51 should be used for these headwaters of the Wanaque. The following table gives the results of gaugings made by Mr. James Fraser at the dam near Pompton station, at the mill of H. J. Smith, Esq.:

FLOW OF WANAQUE RIVER, 1890-1.

Drainage area, 101.0 square miles.

MONTH.	Rain—Inches.	Flow—Inches.	FLOW IN CUBIC FEET PER SECOND.		
			Greatest.	Least.	Average.
1890.					
October	6.95	2.49	594	91	217
November	.77	.93	126	44	84
December	4.02	1.59	799	44	138
1891.					
January	8.51	6.27	4,943	91	549
February	4.50	5.51	1,107	217	548
March	4.25	5.55	914	217	516
April	2.80	1.92	303	92	174
May	2.96	.61	77	45	54
December to May	27.04	21.45	Loss, 5.59 inches.		

This short series of gaugings covers a period when the stream is least affected by draughts from Greenwood lake. A close resemblance to the flow of the Ramapo during the same period is apparent on analysis. From October, 1890, to May, 1891, the Wanaque shows 34.76 inches rainfall and 24.88 inches flow-off. During the same eight months the Ramapo gives rainfall 34.50 and flow 24.95 inches. This, as we should expect, indicates a close equality in the amount of evaporation, and the distribution of the flow throughout the period indicates, also, a strong resemblance in the flow from ground-storage.

Water-supply.—The Wanaque water-shed affords one of our best gathering-grounds for city water-supply, the population being very small, and towns and villages or other possible sources of pollution are entirely absent. For a gravity supply the stream does not offer the best facilities, as it is at a low elevation at all points where any considerable amount can be collected, excepting Greenwood lake and Sterling lake, which we have already noted. To collect 14 inches per annum upon the whole water-shed 7.25 inches of storage should be allowed, and the resulting supply will be 73,000,000 gallons daily. We have seen that storage is already provided for the 28 square miles of water-shed of Greenwood lake, and the 4.69 square miles draining into Sterling lake. Storage for the balance of the water-shed may be obtained in the lower main valley.

Water-power.—While Table No. 53 is the safest for the total amount collectible of this water-shed, Table No. 51 gives most accurately the dry-month flow, consequently we base our estimates of water-power upon this. The water drawn from Greenwood lake averages 4.43 horse-power per foot fall on all the portion of the stream below the lake. The natural flow from this 28 square miles would be 1.94 horse-power per foot fall, so that the amount actually added is 2.49 horse-power per foot fall to the natural flow of the stream. At Pompton lakes we estimate 6.97 horse-power per foot fall to be available from the natural flow. Adding the above, we have about 9.5 horse-power per foot fall. 14.5 horse-power per foot fall is improved in a substantial way at the mills of H. J. Smith, and is said to be satisfactorily obtained, there being considerable pondage. Below the mouth of Ringwood creek the drainage area is 67 square miles, and we estimate 4.62 horse-power per foot fall. At Wanaque, about midway between these points, 6 horse-power per foot fall is successfully used. At the site of the old Freedom furnace, a charcoal blast furnace built in 1838, which was out of blast and in ruins in 1855, there was a crib dam about 200 feet long and 9 feet high with a race 600 feet long and 15 feet fall. The drainage to this pond is about 88 square miles. We estimate the available power at 5.9 per foot fall or 8.4 horse-power, with the draught from Greenwood lake added, making 126 horse-power available at this site, which would be a very steady, reliable power. Just above there is an old forge site which has 9 feet fall. We estimate 5.5 horse-power per foot fall, or 8 horse-power, including storage from Greenwood lake, giving a total of 72 horse-power available. From the mouth of Ringwood creek to Pompton these two old sites and those now in use include all the available power. From Greenwood lake to the mouth of Ringwood creek the total fall is 360 feet, and we estimate the available power to be practically that due to the amount drawn from the lake, or 4.4 horse-power per foot fall. 32.5 feet of this is developed at Ringwood iron works, giving 143 horse-power continuous. There is on this part of the stream a total of 300 feet fall undeveloped, which is good for 1,320 horse-power. If the draught from the lake could be controlled this power would never fall below 1,020 horse-power, and if confined to working hours 2,000 horse-power would be as steadily available as if it were steam-power.

The water-power upon the branches of the Wanaque is of little importance. Near the mouth of Ringwood creek there is an old forge site with ten feet fall and 14.8 horse-power available.

PEQUANNOCK RIVER.

This is another branch of the Passaic, and with the Ramapo and Wanaque it forms the Pompton river just below Pompton. Its drainage area lies high on the Archean Highlands. For nearly its whole course it flows transversely to the ridge and valley structure of these Highlands, thus differing from the Ramapo and Wanaque, which flow through deep valleys. The headwaters of the Pequannock are at an elevation of nearly 1,500, while the mouth, at Pompton, is only 170; consequently the stream has great fall. From Post's dam, at Riverdale, two miles above the junction of the Ramapo, to New Foundland, 12.5 miles above, the fall is 45 feet per mile; thence to Wallace's Corners it is 9.2 feet per mile for 6 5 miles; for two miles above this, to Stockholm, it is 30 feet per mile. The water-shed is six or seven miles wide by 16 miles long, and the branches are quite uniformly distributed along the course of the main stream, mostly coming in from the northeast. Forests cover 78 per cent. of the area.

The first table of gaugings gives the results of a record made at Riverdale by Mr. J. H. Furey. We have to acknowledge the assistance of Hon. John F. Post in securing this record :

FLOW OF PEQUANNOCK RIVER AT RIVERDALE.

Drainage area, 84.7 square miles.

MONTH.	Rain—Inches.	Flow—Inches.	FLOW IN CUBIC FEET PER SECOND.		
			Greatest.	Least.	Average.
1890.					
February	4.45	3.38	686	125	273
March	6.40	4.02	891	155	296
April	2.68	2.70	382	75	205
May 1st to 5th	.31	.20	155	74	91
June					
July					
August					
September 27th to 30th	.58	.08	90	25	45
October	6.95	3.61	959	25	264
November	.77	1.42	301	25	100
December	4.02	1.03	437	25	75
1891.					
January	8.51	5.17	2,352	48	387
February	4.50	5.05	1,384	46	276
March	4.25	4.12	683	46	192
April	2.80	1.50	234	46	215
May	2.70	.62	77	45	53
December to May	26.78	17.49			

The second table of gaugings is compiled from records made by Clemens Herschel, C.E., Chief Engineer of the East Jersey Water Company, at Macopin intake :

FLOW OF PEQUANNOCK RIVER AT MACOPIN INTAKE.

Drainage area, 63.7 square miles.

MONTH.	Rain—Inches.	Flow—Inches.	AVERAGE WEEKLY FLOW IN CUBIC FEET PER SECOND.		
			Greatest.	Least.	Average.
1891-2.					
June	1.76	.55	48	16	31
July	5 01	.27	20	20	15
August	5.75	1.39	254	16	80
September	1.93	.90	90	25	51
October	2.11	.34	23	15	19
November	3.19	1.73	172	16	97
December	4.99	3.77	415	105	212
January	5.95	5.96	450	173	335
February	.99	1.63	115	72	92
March	4.30	2.58	183	125	145
April	1.43	1.73	128	44	97
May	5.39	2.17	190	70	122
June to May	42.80	23.02			
1892-3.					
June	4.33	2.37	221	76	133
July	3.83	.53	40	15	30
August	4.63	.53	40	12	30
September	2 06	.47	53	8	26
October	.71	.16	10	8	8.8
November	6.80	1.53	224	24	86
December	1.55	1.62	140	53	92
January	4.07	1.86	212	50	104
February	6.72	3.73	293	124	212
March	3.55	6.82	614	331	383
April	4.83	4.26	277	196	240
May	5.66	4.98	606	104	280
June to May	48.74	28.86			

COMPARATIVE TABLE OF FLOW FROM OCTOBER, 1890, TO MAY, 1892.

	Rain. Inches.	Flow. Inches.	Difference. Inches.
Pequannock	77.30	45.54	31.76
Ramapo	76.45	44.11	32.34

OCTOBER, 1890, TO MAY, 1891.

	Rain. Inches.	Flow. Inches.	Difference. Inches.
Pequannock	34.50	22.52	11.98
Wanaque	34.76	24.88	9.88
Ramapo	34.50	24.95	9.55

Comparing only the year from June, 1891, to May, 1892, with the same year on the Ramapo, as shown by the table of gaugings for that stream, the flow from the Pequannock is seen to be larger, but if we combine the two tables of flow of the Pequannock we have the results shown in the comparative table above, from October, 1890, to May 1892, a period of 20 months, which shows the flow from the Pequannock to be slightly in excess of that from the Ramapo. From October, 1890, to May 1891, the flow from the Pequannock was considerably lighter than from the Wanaque and Ramapo, a fact which is, no doubt, due to a difference in the amount of depletion of the ground-water, which was less upon the Pequannock at the end of May, 1891, than upon the other streams, consequently there was less water required to make this good, and the flow for the year following appears larger for the Pequannock in consequence. We find the evaporation upon the Pequannock averages about 11.5 per cent. less than what we obtain from the Passaic formula (E equals 15.50 plus 0.16 R). It is evident, therefore, that this is in its evaporation as it is in its topography, a typical Highland stream, to which Table No. 51 exactly applies.

The least flow for a period of one week, shown by Mr. Herschel's gaugings, is 0.13 cubic foot per second per square mile. From flood-marks near the mouth of the river we estimate the flood-flow to be 52.7 cubic feet per second per square mile.

Stickle pond, on Stonehouse brook, has an area of 110 acres and drains 1.7 square miles. There is a dam at the outlet, and the pond was probably constructed to furnish storage to an old forge shown on Gordon's map. Macopin lake has an area of 299 acres, and a water-shed of 2.5 square miles. It can be drawn down 5 feet, and affords all the necessary storage for its water-shed. It is now controlled by the East Jersey Water Company, being a part of their system of reservoirs. Hanks' pond has a stone dam across the outlet 20 feet long and 6 feet high. Cedar pond, recently enlarged for a sportsman's preserve, is also controlled by a dam, and with Buckabear and Hanks' pond above mentioned, was probably intended to furnish storage to the iron works at Clinton Falls, where there was a charcoal blast furnace which went out of blast in 1849. Dunker pond has 17 acres of surface and 2.7 square miles of water-shed.

Water-supply.—The Pequannock is another excellent gathering-ground for water-supply. The population is light and scattering in general. The largest village is Bloomingdale, with a manufacturing population of about 2,000. Above this there is practically no present danger of pollution, unless we except the petroleum oil-pipe line which traverses the entire length of the water-shed, passing near Vernon, Newfoundland, and thence along the line of the New York, Susquehanna and Western railroad. Precautions are taken against serious leakage from this line, which is constantly patrolled, and is not a seriously threatening danger. With 7 inches storage upon this water-shed, 14 inches may be collected annually, equal to a total daily supply of 56,000,000 gallons. Sites for this storage are given in a report of the Commissioners of State Water-Supply made in March, 1884, the stream having been recommended by this commission as a source of supply for our northeastern cities. In the following table I have given these sites with their stated capacity, to which I have added the tributary water-shed and the amount of storage estimated to be necessary at 7 inches on the water-shed:

POSSIBLE RESERVOIR SITES ON THE PEQUANNOCK.

Name of Reservoir.	Elevation.	Capacity. Million Gallons.	Tributary Drainage. Square Miles.	Necessary Storage. Million Gallons.
Bloomingdale	370	1,870	82.0	4,002*
Stonehouse Brook	700	1,000	4.5	330*
Stickle Pond	800	700	1.8	220
No. 3 (Brick Yard)	800	700	1.7	208
Macopin Lake	900	1,250	2.5	305
Hanks' Pond	1,033	300	.7	87
Cedar Pond	1,110	300	1.0	122
Buckabear Pond	1,000	3,800	9.5	1,160
Oak Ridge	880	13,000	26.5	3,240
Dunker Pond	1,043	1,000	2.7	330
				10,004

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* Exclusive of that provided by reservoirs above on same drainage.

It will be observed that in order to secure a uniform storage of 7 inches upon the water-shed we shall need still 2,132,000,000 gallons for the main valley between Oak Ridge and Bloomingdale. Sites at Charlottesburg and on Post's or Kanouse brook, east of New Foundland, will provide a part of this, but the whole will not easily be obtained.

The East Jersey Water Company has established works upon this water-shed for the supply of the city of Newark. Their collection works consist of a dam at Macopin intake, forming a small reservoir on the main stream, from which the steel conduit 48 inches in diameter and 21 miles long draws the supply. Its water surface is 12 acres in extent, and it contains 32,000,000 gallons. It is at an elevation of 584 feet, and the drainage area tributary to it is 63.7 square miles. Table No. 51 shows that in the driest period, with 7 inches storage, 42,600,000 gallons daily may be collected. The storage reservoirs on the water-shed above are Macopin lake, which we have previously described, and which will yield 1,600,000 gallons daily, and the two larger following.

Oak Ridge reservoir is on the main stream near the village of the same name; has an area of 383 acres and a storage capacity of 2,555,000,000 gallons. The dam is an earthen embankment about 40 feet high, with a concrete core-wall 8 feet thick at the bottom and 5 at the top. The outlet channel is a cut blasted through the ledge around the east end of the dam. The water-shed tributary to this reservoir is 27.3 square miles in extent. The storage amounts to 5.38 inches on this area. From Table No. 51 we find that this will maintain the flow in the driest period at .985 inch monthly, or 15,288,000 gallons daily. Clinton reservoir has an area of 423 acres, and receives the drainage from 9.5 square miles. Its capacity is 3,518,000,000 gallons, or 21.32 inches on the water-shed. It is said to have filled between September 4th, 1891, and June 4th, 1892. It will be found by the table of gaugings that during this period the flow from the entire water-shed amounted to 20.81 inches, so that there was probably no difference between the amount flowing off from this 9.5 square miles and the entire 63.7 square miles above Macopin intake. Table No. 51 shows that this reservoir will yield continuously 6,300,000 gallons daily if drawn down to the extent of 7 inches on its water-shed. It may be drawn, of course, to a much greater extent, but in that case will not fill for a long time after.

The 24.4 square miles not provided with storage will yield during the driest period not more than 1,976,000 gallons daily. Adding this to the amount which we allow for the three reservoirs, the whole works would therefore have a capacity of 25,200,000 gallons daily if no reservoir is drawn down more than 7 inches upon its water-shed. If Clinton reservoir is drawn to its utmost capacity, a larger amount may be furnished.

Water-power.—This stream has been a popular one for water-power, as will be seen by our table in the appendix, but all of the sites below Macopin intake have already been, or are in process of being acquired by the city of Newark, or rather the above-mentioned water company, and the stream will not hereafter figure to any extent for water-power. Its development began sometime previous to the Revolution, and reached a high stage at a very early date. The 1850 edition of Gordon's map shows 3 furnaces, 9 forges and 10 mills, or 22 establishments in all using water-power upon the water-shed. This was a larger number than existed in 1890, when the total number of sites was 18. There is no doubt, however, that the total amount of power in use at the later date much exceeded that in use in 1850, or previously. We estimate 5.52 horse-power per foot fall available at Bloomingdale, and we find from 10 to 14.8 horse-power per foot fall improved. Ten horse-power seems to have been successfully used before the stream was developed to supply the city of Newark. This was during working hours. The total amount of fall improved at Bloomingdale is 139 feet, and 183 feet is in use between Smith's mills and the mouth of the river.

At Charlotteburg there is a stone crib dam 220 feet long and 14 feet high, and a raceway about 200 yards in length. There is 19 feet fall and a considerable pondage. A charcoal blast furnace was built here in 1767 and operated for a short time. In 1840 a forge was built and an extensive business carried on for several years. We estimate 4 horse-power per foot fall, or 76 horse-power of continuous power, to have been available here. This upper part of the water-shed has been appropriated for the supply of the city of Newark, and we shall not consider it further as a water-power stream.

ROCKAWAY RIVER.

This is the next branch of the Passaic to the south, and is a Highland stream with a strong resemblance to the Pequannock in the character of its water-shed. It also flows southeast, across the Highland ridges, but its fall is less uniform than that of the Pequannock. For six miles above its junction with the Passaic the fall of the Rockaway is 2.3 feet per mile; thence to Old Boonton, two miles up, it is 32 feet per mile. This is at the base of the Highlands at the west side of the Central Passaic valley, and the river has a rapid descent as it issues from the plateau. From Boonton to Old Boonton, 1.5 miles, the total fall is 240 feet, affording one of the fine water-powers of the State. For 11 miles above, to Dover, the fall is but 7.3 feet per mile, and thence to Woodstock, 12 miles by the stream, it is 16 feet per mile. From source to mouth, the stream is 40 miles in length. The area of the water-shed is 138.4 square miles, and 80 per cent. is in forest. A gauge was set up at Dover, and read by Messrs. Smith and Jenkins. It was impossible to obtain the flow at this point excepting on Sundays, when the mills were shut down. The gaugings are given as they were taken:

FLOW OF THE ROCKAWAY AT DOVER, 1890.

Drainage area, 52.2 square miles.

DATE.	Cubic feet per second.	Inches on water-shed in 24 hours.	DATE.	Cubic feet per second.	Inches on water-shed in 24 hours.	DATE.	Cubic feet per second.	Inches on water-shed in 24 hours.
March 30th...	253	.180	July 6th...	80	.057	Oct. 5th...	136	.097
April 6th...	182	.129	" 20th...	39	.028	" 12th...	104	.074
" 13th...	182	.129	" 27th...	272	.194	" 19th...	159	.113
" 20th...	115	.082	August 3d...	318	.226	" 26th...	208	.148
" 27th...	115	.082	" 17th...	39	.028	Nov. 2d...	116	.083
May 4th...	175	.125	" 24th...	78	.056	" 9th...	88	.063
" 11th...	103	.071	" 31st...	78	.056	" 16th...	88	.063
" 18th...	182	.129	Sept. 7th...	50	.036	" 23d...	61	.043
" 25th...	121	.086	" 14th...	165	.117	Dec. 7th...	88	.063
June 1st...	128	.091	" 21st...	129	.092	" 14th...	43	.031
" 8th...	110	.078	" 28th...	89	.063	" 21st...	88	.063
" 15th...	115	.082	" 30th...	39	.028			
" 22d...	115	.082						
" 29th...	41	.029						

The above gaugings indicate a very large summer flow. The water-shed above Dover includes that of the Longwood valley above Port Oram, which is described under the gaugings at that point; and also the water-shed of Green Pond brook, 16.4 square miles in area. This latter shed has pondage aggregating 728 acres in area, and some swamps. A draught of 16 inches on this pondage would add an inch to the flow of the water-shed, and a draught of 2 feet would add half an inch to the flow of the entire shed above Dover. Comparing these gaugings with those at Port Oram, just above, they are found to indicate a much larger proportional flow, and I have not considered it safe to base any conclusions upon this Dover series, as there is danger that the flow is increased by large draughts upon artificial storage, which have been noted.

Another gauge was set up at the new mill of the Luxembourg Improvement Company, at Port Oram, and read from November 15th to January 15th by Mr. N. J. Peltier, the superintendent:

FLOW OF ROCKAWAY RIVER AT PORT ORAM, 1890-1.

Drainage area, 29.9 square miles.

MONTH.	Rain—Inches.	Flow—Inches.	FLOW IN CUBIC FEET PER SECOND.		
			Greatest.	Least.	Average.
November 15th to 30th	.36	.59	33	24	30
December	4.32	.95	34	12	24
January 1st to 15th	2.90	2 20	409	31	120

September 10th, 1894, minimum flow, 11.1 cubic feet per second, was observed by Geo. E. Jenkins, C.E., from the filling of the pond in twenty-four hours.

The Rockaway, above Port Oram, flows through Longwood valley with a fall averaging about 10 feet to the mile. The bottom of the valley contains considerable beds of drift gravel, and there is also some marsh on the lower part of the stream. These features contribute to produce a steady and well-sustained dry-season flow. The hills rise about 600 feet above the valley, and 90 per cent. of the water-shed is in forest. Inquiry along the stream indicates that the above minimum flow of 11 cubic feet per second is as low as the stream falls, except in extremely dry periods.

Mr. Charles F. Swain furnishes the following gaugings, made in 1890, at Boonton:

August 6th, 109 cubic feet per second.
August 15th, 136 cubic feet per second.
September 9th, 80 cubic feet per second.

The latter was believed to fairly represent the flow of the stream, although it is much involved with the flow of Morris canal. The area above this point is 118 square miles, and at this same date we found the Ramapo discharging at the rate of 92 cubic feet per second on 160 square miles, which is a little lower rate than that of the Rockaway. From high-water marks, we find the maximum flood-flow at Boonton to be 40.7 cubic feet per second per square mile, and at Dover 43 cubic feet per second per square mile, showing a rate about two-thirds of that given by the Ramapo. From these records of flow and a knowledge of the surface geology of the water-shed, we adopt Table No. 52 to represent the flow of the Rockaway.

Lakes and ponds.—Dixon's pond, near Rockaway valley, is a mill-pond with a stone dam 140 feet long and 10 feet high. The area is 35 acres and it receives the drainage of 3.53 square miles. On Den brook, Opennaki lake, is an old forge site with a stone dam 60 feet long and 12 feet high. The pond is small. Just above is Shongum, 70 acres in extent, with 2.9 square miles drainage area. The dam is 150 feet long and 12 feet high. This is also an old forge site. Split Rock pond was improved for storage to furnish power to a charcoal blast furnace. It is 315 acres in extent, with a water-shed of 5.3 square miles. The dam is of stone. If raised 3.5 feet and then drawn off 7 feet it would form an excellent reservoir with a capacity of 718,000,000 gallons, or over 7 inches on its water-shed, and would supply continuously 3,500,000 gallons daily. The elevation is 315 feet. Durham pond is on the same water-shed just above, and has an area of 47 acres, with less than one square mile tributary water-shed. It was a forge site from 1811 to 1856. On Green Pond brook, Middle Forge pond has a stone dam 132 feet long and 13 feet high. This was an old forge site dating back to 1810, and there was 15 feet fall at the water-power. The area of the pond is 96 acres and its water-shed is 10.1 square miles. Under present conditions, there is a difference of 4 feet between the highest water level and the lowest possible, giving about 0.7 inches on the water-shed. Denmark pond was also a forge site, dating about 1800, and is 172 acres in extent with about 4.5 square miles of water-shed. The dam is of stone, 145 feet long by 25 feet high, 30 feet fall having been available. From the highest to the lowest water-level, as the gates are now arranged, this pond probably affords about 4 inches storage on its water-shed. Green pond, upon the same water-shed, is a beautiful natural lake at an elevation of 1,048 feet. It has an area of 460 acres, with a drainage area of but 1.7 square miles. It would only be necessary to draw this lake down 1 foot to afford 7 inches of storage on its water-shed. In this way the lake could be made to supply 1,200,000 gallons daily in the driest period.

In Longwood valley, at Lower and Upper Longwood, there are quite large ponds upon the Rockaway. Still farther up is the Petersburg mill-pond, 53 acres in extent, and Mooseback pond, 21 acres in extent, the lake having a very small water-shed. It will be seen that at present the Rockaway has a very considerable amount of storage, and even though they are not drawn down, these various ponds contribute substantially to keep up the dry-season flow of the stream by leakage through their dams, or discharge over the weirs.

Water-supply.—The portion of the Rockaway river below Boonton flows through the red sandstone valley, but 118 square miles of the water-shed above Boonton falls is purely a Highland area, ranging from 500 to about 1,200 feet in elevation. On this portion of the stream the valleys are mostly rather flat, and very largely covered with drift gravel and sand. In consequence, the water rushing down from the upper, steeper slopes does not find its way immediately into the stream. It is largely passed through the sand and gravel, and thus naturally filtered. Our table of drainage systems in Appendix II. shows that the Rockaway has a population of 113 to the square mile above Boonton, and 82 per cent. of the area is in forest. By reason of its high elevation at a point so near to our large eastern cities, and the fact that its water-shed lies entirely within the State, in addition to its topographical and geological advantages, the Rockaway ranks first among our unused sources of water-supply, and it needs to be considered by us with some care. The only points above Boonton where pollution seems to be at all seriously threatened are Dover and Rockaway, the former having a population of about 3,500, and the latter probably not over 500. Outside of these towns the population is widely scattered, and is largely a mining population. Just at present this mining population is decreasing, and there is no likelihood of its future increase to any serious extent. The following table shows the population in 1880 and 1890, with Dover and Rockaway returned separately :

Township.	Area. Square Miles.	Population. 1890.	1880.
Boonton, exclusive of Boonton City	6.87	326	405
Rockaway, exclusive of Rockaway Village	63.34	5,533	6,966
Randolph, exclusive of Dover	27.85	4,572	4,742
Jefferson	44.26	1,611	1,792
Totals	142.32	12,042	13,905

POPULATION OF VILLAGES.

Dover, 1880.................. 2,958. 1885... 3,170. 1890,............ 3,400.
Rockaway, 1880, estimated, 400. 1890, estimated, 500.

The above table, which has been compiled from census returns, shows that, exclusive of Dover and Rockaway, the population has decreased 16 per cent. during these ten years. Since 1890 some large and important mines have been abandoned, and, in consequence, the decrease has been at a still more rapid rate. The position of the water-sheds is such that the sewage of Dover and Rockaway may be readily conducted out. It will consequently be seen that there need be no apprehension of danger of serious artificial pollution on the Rockaway above Boonton, and that the facilities for removing any possible contamination are exceptionally good. It is very important, not only to the preservation of the purity of the stream, but to the general health of the district, that the Rockaway should not be used as an outlet for sewage, as its dry-season flow is too small to permit of this with safety.

The water-shed above Boonton falls will supply 78,000,000 gallons daily, with storage amounting to 7 inches. The following table gives some possible reservoir sites upon the water-shed, with their capacity:

STORAGE RESERVOIRS ON ROCKAWAY RIVER.

Name.	Elevation.		Drainage Area.	Area of Surface.	Capacity.
	High Water.	Low Water.	Square Miles.	Acres.	Million Gallons.
Dixon's Pond.............	580	565	3.53	154	471
Rockaway Valley........	523	500	9.2	276	1,250
Beach Glen...............	540	520	22.1	786	3,793
Split Rock.................	818	811	5.3	315	718
Middle Forge............	710	700	10.1	.....	1,240
Denmark	818	810			
Green Pond...............	1,048	1,047			
Berkshire..................	700	690	4.4	320	825
Longwood.................	740	700	22.4	502	3,569

The above reservoirs furnish storage for 71.7 square miles. To supply the remaining 46.3 square miles, 5,650,000,000 gallons will still be needed, which may be provided on the main stream, Den brook, Mill brook and in lateral reservoirs, with no difficulty.

Any of these reservoirs will supply 666,094 gallons daily for each square mile of water-shed.

Water-power.—There is a strong probability that in the near future the Rockaway will be developed for the supply of some of our large cities, consequently it will lose its importance as a water-power stream. We have not anywhere in this report considered the Whippany as a part of the Rockaway water-shed. It joins the Rockaway very near where the latter flows into the Passaic, and has nothing in common with the latter water-shed, so that it is more convenient to consider the two separately. We estimate the available power of the Rockaway at its mouth to be 9.25 horse-power per foot fall. At Boonton falls we make it 8.14 horse-power per foot fall. Between these points we find from 7 to 12 horse-power improved. Below Old Boonton there is about 50 feet of fall unimproved. Between these points and the head of Boonton falls there is 240 feet fall, of which 142 is improved, 112 of this being at the site belonging to the estate of J. Couper Lord. There is a good deal of pondage above the head of the falls. We estimate the lowest flow to be at the same rate as upon the Ramapo, which would give 16.52 cubic feet per second at the head of the falls. It is claimed that the flow of the Rockaway here is considerably increased by water drawn through Morris canal from Lake Hopatcong. Messrs. Croes and Howell, in their report to the Newark Aqueduct Board in 1879, estimated the leakage of this canal to be 1.74 cubic feet per second per square mile, or 50.46 cubic feet between Lake Hopatcong and Pompton feeder. As we have at times observed a flow of 55 cubic feet per second through the canal eastward from Lake Hopatcong, and have also observed that, as a rule, very little water passes eastward through the aqueduct over Pompton river at Mountain View, it seems probable that this estimate is not far from the truth. As the canal between Boonton and Pompton feeder must have its full proportion of leakage, and also requires water enough to operate the planes, it is difficult to see how the addition to the Rockaway can be any more than the proportionate leakage for the 14 miles of canal which traverses the Rockaway water-shed above Boonton. Assuming this to be true, it gives us 24.4 cubic feet per second added to the flow of the Rockaway by leakage from the canal. This would make the total flow of the Rockaway below Boonton 40 cubic feet per second, or 4.5 horse-power per foot fall.

The Morris canal, it has been claimed, does not divert water from the Rockaway, although it locks its boats into the river at Dover, and again at Powerville, which is above Boonton falls. With a moderate amount of storage to maintain the flow during the extreme dry periods this water-power at Boonton could be made a very valuable one if utilized to the full extent of 240 feet fall. Like most of the other water-powers of northern New Jersey, it was originally improved for use in iron manufacturing, a very large business having been carried on at one period.

At Powerville, just above the falls, we find 27 horse-power per foot fall improved, but steam-power is used in connection with this. There is little available power above this point until we reach the village of Rockaway. Here 19 feet is improved, having been used originally for two forge sites, dating back to 1790. At Dover, we estimate the available power at 3.48 horse-power per foot fall, and find about this amount improved, with a large allowance of pondage. There is about 50 feet fall unused between here and Port Oram. At the site of the old Washington forge there is a pond of 10 acres, the water-shed being 29.9 square miles. We estimate the available power to be 2 horse-power per foot fall. On September 10th, 1894, the flow for 24 hours at this point amounted to 11.1 cubic feet per second. This was a very dry time, and while this flow amounts to 0.37 cubic feet per second per square mile, or double that of the Ramapo, at the same time the stream seems to very rarely fall below this, and probably has a minimum of not much less than 0.3 cubic feet per second per square mile. This would make the driest season give 1.1 horse-power per foot fall, or twice this for working hours, with the existing pondage. We find 3.75 horse-power improved, and at Baker's mills, the next site above, 4.8 horse-power. Just above this, near the crossing of the Delaware, Lackawanna and Western railroad, was the site of Valley forge, which had 7 feet fall.

At Lower Longwood, there is another old forge site, connected with which was a saw-mill. The dam is of earth and stone, 200 feet long and 12 feet high. The water-shed is 21.1 square miles, and the available power 1.4 horse-power per foot fall, or 16.8 in all, there being sufficient pondage to double this during working hours. At Upper Longwood, there is another forge site. The dam is of cribwork, in a rocky gorge, and is 75 feet long and 15 feet high. We estimate 19.5 horse-power for this fall, or double this for working hours, there being a large pond. Another forge site at Woodstock has 7 feet fall, and at Petersburg there is still another with a large pond and 12 feet fall, for which we estimate 9.6 horse-power, or double this for working hours. All of these powers have the reputation of being very good and steady, and this is borne out by appearances. There were several more forge sites, some of them on very small water-sheds, above this pond.

Split Rock pond, to which we have already alluded, was improved to furnish storage for, first, a forge, in about 1837, and later, a charcoal blast furnace. It is another example of a small water-shed highly developed, to furnish power for iron manufacturing. The dam is of dry stone in a rocky gorge and is 90 feet long and 10 feet high. Two falls were used for the furnace, one of 28 and one of 7 feet. Three feet draft upon the pond gives about 2 inches storage upon the water-shed, and will maintain the flow at 1 inch monthly in an ordinary dry year, making 0.53 horse-power throughout such a year, and 0.37 horse-power in the driest period for each foot of fall. Doubling these figures for working-hours, we have at this site 49 horse-power throughout an ordinary dry year, and 26 horse-power even in the driest. On the outlet, there is a total fall of 255 feet in about 1 mile. At Beach Glen, a forge was built as early as 1760, and this also had a large pondage. The dam was of earth and dry stone, 200 feet long and 10 feet high, and the pond was nearly a mile in length. The water-shed was about the same as that of Split Rock, but the power could not have been more than one-third.

At Middle Forge the effective storage, including Denmark pond, was about 1.5 inches upon the water-shed, which is 10.1 square miles in area, and we estimate 13.9 horse-power on the 15 feet fall, or say 28 horse-power during working hours. At Denmark the effective pondage was about 3 inches upon the water-shed of 4.5 square miles, and the fall being 30 feet, 13.5 continuous, or 27 horse-power during working hours, must have been available throughout an ordinary dry year. It would appear that for these forges upon the Rockaway water-shed in the neighborhood of 30 gross horse-power was aimed at as the available power. The number of sites developed for this purpose seems to have been 37, 3 of which were for furnaces and 34 for forges, according to the 1850 edition of Gordon's map. There are 24 mills also using water-power, making 61 establishments in all. All of the sites now in use were developed before that date, and probably most of them before 1830.

WHIPPANY RIVER.

The next branch to the southward is the Whippany, which rises near Mt. Freedom, about six miles west of Morristown, and flows a little north of east, joining the Rockaway less than a mile above its junction with the Passaic. The water-shed is 71.1 square miles, of which 25.4 square miles above Morristown is in the Highland region. The remainder lies almost entirely upon the red sandstone within the Central Passaic valley. This portion is covered with large beds of drift, being crossed by the terminal moraine. The largest branch of the Whippany is Troy brook, draining 15.2 square miles. The Whippany is said to carry a good deal of sediment in floods. We have no measurements of the maximum flow, but indications point to about 40 cubic feet per second per square mile, or about the same as the Rockaway. The minimum flow at Whippany is probably not less than 0.17 cubic feet per second per square mile, while above Morristown it is probably somewhat less. Table No. 52 will be safe to apply to this for dry-season flow, but evaporation is probably greater, and the total run-off will agree more closely with Table No. 53.

Water-supply.—The population upon the Whippany water-shed is large and increasing. The stream is not well adapted to become a source of water-supply, although some of the smaller branches may afford good local supplies of limited amount.

Water-power.—A considerable amount of power is in use upon the Whippany, and seems to have been improved at a very early date. There was a forge site at Whippany about 1710. In 1850 all the sites which are now in use seem to have been improved. We estimate the power at Whippany to be 2.75 horse-power per foot fall, and at Speedwell lake 1.70. We find 4.3 horse-power improved at Whippany, and even higher at some mills, the average being about 5 horse-power. The pondage is good, there being a succession of quite large mill-ponds. At Morristown two mills use 3.75 horse-power per foot fall. Of the 140 feet fall from Morristown to Whippany, 124 is in use, so that the stream seems to be fully developed.

MORRIS CANAL.

This is one of the important hydraulic works of the State, and deserves some attention in this connection, although the amount of business carried on is much less than formerly. It was built by the

WHIPPANY WATER-SHED—SUGAR LOAF TO WATNONG MOUNTAIN.

Morris Canal and Banking Company, being completed in August, 1831. It is about 102 miles in length, beginning at Jersey City, and running thence through Newark, Paterson, Boonton, Dover, Hackettstown and Washington to the Delaware river, at Phillipsburg, where it connects with the Lehigh Coal and Navigation Company's canal, following the Lehigh river to Mauch Chunk. It was designed for coal-carrying and local trade. Its summit level is 913 feet above mean tide, and is near Lake Hopatcong, from which the canal derives its water-supply. The Delaware, at Easton, is about 156 feet, so that a boat in crossing the State is moved vertically a total distance of 1,672 feet. The ascent from Jersey City to Lake Hopatcong is accomplished by 12 inclined planes and 16 locks, and the descent to Delaware river by 11 planes and 7 locks. These planes are inclined railways. A cradle descends to the bottom of the canal so that a boat can be floated into it and secured, then the cradle is hauled by a cable operated by water-power to the next level above. The wheels in use to operate these planes are the simplest kind of reaction wheels. They are usually operated under a head somewhat less than the total lift of the plane. The following table gives the distances of the locks and planes from Jersey City, and the elevation of the several levels of the canal taken from field notes of the topographical survey:

HEIGHTS AND DISTANCES ON MORRIS CANAL.

	Distance. Miles.	Elevation. Feet.
Head of Locks 18, 17, 16, at Newark	12	30.4
Plane 12, at Newark	13	100.4
Lock 15, above Newark	13.9	109.5
Lock 14, near Bloomfield	......	119.8
Plane 11, near Bloomfield	19	173.7
Pompton Feeder, Mountain View	35.2	174.9
Lock 13, near Pompton River	......	181.7
Plane 10, near Pompton River	38.3	237.9
Plane 9, Montville	......	322
Plane 8, Montville	42.5	388
Lock 12, near Boonton Falls	43.6	398.9
Plane 7, Boonton Falls	44.1	480.7
Lock 11, Boonton	44.5	489.6
Locks 10, 9, Powerville	45.5	504.5
Lock 8, Denville	48	511.8
Plane 6, Rockaway	50.6	563.1
Locks 7, 6, at Dover	54.2	581.2
Locks 5, 4, above Dover	55	599.2

	Distance. Miles.	Elevation. Feet.
Head of Plane 5, above Dover	55.6	665.2
Lock 3, near Baker's Mills	......	673.2
Plane 4, Baker's Mills	57.5	725.4
Locks 2, 1, near Drakesville	......	735.5
Plane 3, near Drakesville	61.1	783.5
Plane 2, Drakesville	61.4	863.5
Plane 1, Summit	62.6	913
Hopatcong Feeder	63.5	913
Foot of Plane 1, Great Meadow	64.7	856.9
Plane 2, Stanhope	66	786.9
Lock 1, near Sayres	......	774.7
Plane 3, near Sayres, Waterloo	67.8	719.7
Plane 4, Old Andover	68.6	639.4
Lock 2, Guinea Hollow, Saxton Falls	71.7	630
Plane 5, near Port Murray	82.6	567.1
Plane 6, Monte Rose, Port Colden	84.5	516.9
Lock 3, near Monte Rose, Washington	......	506.8
Plane 7, Pohatcong	87.6	433.4
Lock 4, near North Village	94.5	423.3
Plane 8, Hulsizers, Stewartville	96.2	361.2
Plane 9, near Lopatcong	92.7	261.8
Plane 10, near Greene's Mills	100.1	216.6
Lock 5, near Greene's Mills	......	208.2
Locks 6, 7, near Greene's Mills	......	190.2
Plane 11, Delaware River, Easton	102.3	155.2

The width of the canal at surface is generally about 40 feet, at bottom 25 feet, and the depth is 5 feet. At Little Falls, the Passaic is crossed by a stone aqueduct bridge about 45 feet high. The Pompton is crossed by a low aqueduct. At Powerville, the canal locks its boats into and out of a pond in the river, so that the flow of canal and river is commingled, and at the head of Boonton plane, the canal is used for a short distance as a head-race for the water-power of the J. Couper Lord estate, the whole flow of the river being taken into the canal during dry seasons. The owners of this water-power are entitled to all of the flow of the canal at this point, excepting what is needed for purposes of navigation between here and Pompton feeder. Near Denville, the Rockaway is again crossed by an aqueduct bridge, and at Dover, boats are locked into the river and the flow is again commingled. On the western slope, the canal and Musconetcong river are much commingled until Saxton Falls is reached, but from this point to the Delaware no streams are taken into the canal excepting some minor branches of the Musconetcong and Pohatcong, and also Lopatcong creek. The boats used upon the canal have a length over all of about 87 feet, and a width of 10 feet 5 inches. They weigh, empty, from 16 to 19 tons, and their loads average 71 tons.

The canal is supplied with water from Lake Hopatcong at the summit, which has 25.4 square miles of drainage area and storage amounting to about 18.5 inches on the water-shed, by a feeder about 1 mile in length, which is navigable, and at the head of which boats may be locked into the lake. Before the building of the railroad to Lake Hopatcong, connecting with the Ogden Mine railroad, there were ore docks at Nolan's point on the lake, 2.6 miles above the outlet, and the canal received a considerable amount of freight from this point. Lake Hopatcong, at 14 inches per annum on its water-shed, would furnish 26.16 cubic feet per second continuously, or in ordinary dry years, 31.8 cubic feet per second could be drawn. On the Musconetcong, below the lake, is Stanhope reservoir, also used to supply the Morris canal. It has an area of 339 acres and a water-shed, exclusive of that of Lake Hopatcong, of 4.9 square miles, and it would furnish 5.05 cubic feet per second. Messrs. Croes and Howell state that the Stanhope mill has rights to a flow from these water-sheds, and that an opening of 10 by 36 inches is kept for the purpose of supplying the mill. We are unable to verify this, but found no evidence of such an opening at Stanhope. Such an opening under 3 feet head would deliver about 20 cubic feet per second, which would be a very large proportion of the whole available flow.

Bear pond, on a branch of Lubber's run, is another reservoir of the canal, having an area of 38 acres and a drainage area of 0.58 square mile. It can be drawn down 12 feet, and will furnish 0.6 cubic feet per second, or 0.7 in an ordinary dry year. Cranberry reservoir, on another branch of Lubber's run, has an area of 154 acres, a water-shed of 3.02 square miles, and will furnish 3 cubic feet per second in the driest year, 3.5 in an ordinary dry year. Greenwood lake is another important reservoir of the canal which we have already described in our treatment of Wanaque river. At 14 inches per annum upon its water-shed it will furnish 28 cubic feet per second. In an ordinary dry year 34 cubic feet may be drawn. These figures are all for continuous draught throughout the year. The season of navigation is usually not more than 7 months, but the canal remains full during the winter, although the draught is, of course, much lighter.

The water from Greenwood lake flows down the Wanaque, and Pompton feeder draws its water from a pond which receives also the flow of the Ramapo and Pequannock. This feeder is navigable, and the Ramapo river is, also, up to Pompton Steel Works, and the canal delivers freight at this point. The feeder is 4 miles long, connecting with the canal proper at Mountain View, on the east bank of the Pompton river. At the head of Pompton feeder our gaugings show a draught of from 40 cubic feet per second in November to 49.5 cubic feet per second in September, and observations indicate a draught of about 50 cubic feet per second for July, August and September, 40 cubic feet for October, November, May and June, and 30 cubic feet per second from December to April, making the average about 38 cubic feet per second for the year. At the aqueduct at Mountain View, which is just west of the mouth of the Pompton feeder, we have observed that the flow varies from 0 to 18 cubic feet per second, probably averaging 8 cubic feet per second, which is the amount required for lockage. Messrs. Croes and Howell, in December, 1878, observed a flow of 62.83 cubic feet per second eastward from Mountain View. It will be noted that if our above summer draught to Pompton feeder is added to 8 cubic feet through the aqueduct, it makes a total of 58 cubic feet per second, or a little less than this gauging. At Little Falls aqueduct our gaugings seem to indicate a summer flow of 58, and a winter flow of 47 cubic feet per second.

Our gaugings also give 55 cubic feet per second flow eastward from Lake Hopatcong and 73.5 cubic feet per second drawn through Hopatcong feeder, indicating a flow westward of 18.5 cubic feet per second. Below Saxton Falls the average opening of the gate drawing water from the river indicates a draught of 36.4 cubic feet, to which we must add lockage of 8 cubic feet per second, giving a total of 44.4. At Washington, in October, 1890, we observed 41.4 cubic feet per second.

Most of the water used by the canal is to make good the leakage. Owing to the manner of construction and the location of the canal, which is largely on side hills, this leakage is large, and may be seen throughout the length of the canal, running away in small rivulets to the streams. Messrs. Croes and Howell made measurements in 1878 and 1879, indicating a leakage of 1.74 cubic feet per second per mile. They also estimated that the amount of water required for lockage at Bloomfield at the time of the heaviest known traffic, which aggregated 6,571 lockages in 200 days, would require a continuous flow of 7.95 cubic feet per second.

We have made studies of the plane at Washington, which has a length of 1,000 feet and a lift of 73 feet, and represents a fair average of the planes on the canal. The wheel operating the plane works under a head of 47 feet. Gaugings of the flume made during the passage of a loaded boat show that 484 gross horse-power was used for 330 seconds to accomplish the lift. To haul up the empty cradle requires 268 gross horse-power used 248 seconds. This indicates the use of about 283 horse-power 330 seconds to haul up the loaded boat alone, the weight of which was 90 tons, and indicates the efficiency of the wheel to be only about 30 per cent. Probably it is actually somewhat higher than this if working continuously. If we suppose that the lockages noted above at Bloomfield were one-half loaded boats going eastward, and one-half empty boats going westward, we find that on the west slope of the canal this amount of traffic would require 5.4 cubic feet per second of flow to operate the plane. The total lift of the planes being 691 feet, 424 gross horse-power continuous must have been used in all. On the east slope about 60 per cent. of the power per foot fall used on the western slope would be required, and the total lift of the planes is 758 feet, so that the total power used here would be 280 horse-power continuous, making a total of 704 horse-power used to operate the canal during the season of heaviest traffic. This amount of horse-power does not appear in our table in the appendix of developed water-power. It will be noted that the amount of water used by the planes is considerably less than that estimated for lockages by Messrs. Croes and Howell. The above 8 cubic feet per second required for lockage must be allowed for throughout the whole extent of the canal.

From Hopatcong feeder to Saxton Falls, in the Musconetcong valley, we have seen that the canal and river flows are commingled, and the leakage of the canal flowing into the river is used again for the canal. From Saxton Falls to the Delaware is 30.6 miles, and the leakage at 1.74 cubic feet per mile amounts to 18.44 cubic feet per second, making 26.4 cubic feet per second for leakage and lockage combined. This is 17.8 cubic feet in excess of what we have noted above as the supplying capacity of Stanhope reservoir and Bear pond and Cranberry reservoirs combined. Our gaugings show 18.5 cubic feet per second drawn westward from Lake Hopatcong. From Lake Hopatcong eastward to Pompton feeder is 28.3 miles, and the leakage and lockage combined amount to 57.2 cubic feet per second, agreeing well with our gaugings, which show 55 cubic feet. From the head of Pompton feeder to Newark the distance is 27.2 miles and the leakage 48.3 cubic feet per second. It is to be noted that the lockage in this case is provided for by the average amount flowing through Pompton aqueduct, so that the above leakage is all that must be actually furnished from Pompton, and this agrees quite closely with our gaugings of summer flow. If the canal had to rely entirely upon its reservoirs above noted, it would appear that there must be a shortage of water during the driest period, but the opportunities afforded at various points for drawing from other streams make it improbable that these reservoirs are the sole reliance. They could readily be made to furnish all of the water required during an extremely dry time, but whenever the various streams furnish a sufficiently large flow to admit of it without interfering with the rights of other users of the water, the draught from the reservoirs could be very much diminished, so that we cannot gather from the use of these reservoirs upon the Morris canal any warrant for supposing a larger total amount of water collected than we have estimated in our tables.

RED SANDSTONE STREAMS.

We now come to a class of streams which differ in a marked degree, in all important respects, from those of the Highlands. The average elevation of the Highlands may be taken at about 850 feet, while that of the Red Sandstone plain does not exceed 200. This difference in elevation alone would account for a difference of about 2 degrees in mean temperature. Our table of mean annual temperature shows an actual difference of 3.2 degrees, corresponding to an increase of 16 per cent. in evaporation, and this is about the amount of difference in evaporation actually shown between the gaugings of the Pequannock and those of the Hackensack and Raritan. The position of the Red Sandstone plain will be best understood by reference to a geological map of the State. It presents two distinct types of topography, the glaciated and the unglaciated, the former being to the northward of the moraine line, which runs through Morristown, Plainfield and Perth Amboy, is heavily covered with drift, and has about 30 per cent. of its area forested, some of this being the heaviest timber in the State. The southwestern portion of the plain has practically no sand or gravel, and only 12 per cent. in forest, is highly cultivated and largely under-drained, having practically none of the marshy areas of the glaciated portion. Saddle river, the Hackensack, Elizabeth and Rahway rivers have their water-sheds upon the glaciated portion, while the Raritan and a few minor branches of the Delaware drain the remainder. These latter streams carry a large amount of silt, the soil being highly soluble, and the red color gives them an especially objectionable appearance during floods. The northeastern streams receive a large portion of their waters after they have been filtered through the sands and gravels, and are somewhat less muddy, although by no means free from this objection. We present herewith three tables representing different types of flow. No. 54 is based upon the flow of the Hackensack, to which it especially applies, but is also applicable to the Elizabeth and Rahway. No. 55 applies to the larger streams of the Lower Raritan water-shed, and No. 56 to some of the smaller branches of the Raritan and the Delaware. Saddle river belongs to this class of streams, but has already been considered under the Passaic water-shed, and being somewhat peculiar in its position and topography, we have considered it best to apply to it Table No. 53.

TABLE No. 54.

Estimated Flow of Northern Red Sandstone Water-Sheds with Drift-Covered Areas and Large Ground-Flow.

AVERAGE YEAR.

	December.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	Year.
Inches of rainfall	3.72	3.63	3.45	3.72	3.63	4.04	4.04	4.23	4.59	3.72	3.45	3.72	45.94
Inches flowing off	2.50	2.97	2.78	2.83	2.34	1.98	1.27	.88	.79	.81	.97	1.60	21.72
Flow in thousand gallons daily per square mile	1,620	1,660	1,665	1,585	1,355	1,110	770	493	442	470	544	927	1,030
Horse-power on one foot fall per square mile	.285	.293	.295	.279	.239	.195	.119	.087	.078	.082	.095	.163	.185

ORDINARY DRY YEAR.

	December.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	Year.
Inches of rainfall	4.04	4.12	1.71	3.02	2.67	3.44	3.82	4.55	4.00	1.01	2.14	2.28	36.80
Inches flowing off	3.18	3.41	1.22	2.20	2.08	1.45	1.03	.82	.74	.66	.55	.66	18.00
Flow in thousand gallons daily per square mile	1,780	1,910	731	1,230	1,210	810	599	459	414	382	308	382	857
Horse-power on one foot fall per square mile	.314	.337	.128	.217	.212	.143	.105	.081	.073	.067	.054	.067	.151

DRIEST PERIOD.

	December.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	Year.
Inches of rainfall	4.05	3.66	4.76	3.83	.61	2.71	3.87	0.96	1.18	.94	3.04	2.02	31.63
Inches flowing off	3.18	2.99	3.94	2.93	1.50	.88	.77	.60	.23	.22	.22	.22	17.68
Flow in thousand gallons daily per square mile	1,780	1,670	2,355	1,645	868	493	446	336	129	127	123	127	843
Horse-power on one foot fall per square mile	.314	.295	.415	.290	.153	.087	.078	.059	.023	.022	.022	.022	.148
Continued.													
Inches of rainfall	2.63	4.57	4.22	3.57	2.12	5.06	1.90	1.37	6.40	12.09	1.32	.99	46.24
Inches flowing off	.23	.72	1.32	2.60	1.93	1.65	1.04	.67	.53	3.58	1.70	.97	16.94

The depletion at end of average year is 0.39 inches, and this is deducted from December flow. To utilize 14 inches per annum, or 666,094 gallons daily, in driest period, 6.41 inches storage is needed, and reservoirs will not be full for over 20 months. To utilize 12 inches per annum, or 570,938 gallons daily, 4.91 inches of storage will suffice, and reservoirs will be drawn down only 16 months in driest period. This is the utmost that can be utilized safely. For 9 months of ordinary dry year, .073 horse-power on 1 foot fall for each square mile of water-shed.

TABLE No. 55.

Estimated Flow of Raritan River—Red Sandstone Streams with Medium Ground-Flow.

AVERAGE YEAR.

	December.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	Year.
Inches of rainfall	3.72	3.63	3.45	3.72	3.63	4.04	4.04	4.23	4.59	3.72	3.45	3.72	45.94
Inches flowing off	2.89	2.97	2.78	2.83	2.34	1.87	1.12	.59	.47	.61	1.13	2.12	21.72
Flow in thousand gallons daily per square mile	1,620	1,660	1,665	1,585	1,355	1,020	650	331	263	353	635	1,250	1,030
Horse-power on one foot fall per square mile	.285	.293	.295	.279	.239	.184	.114	.058	.046	.062	.111	.216	.182

ORDINARY DRY YEAR.

	December.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	Year.
Inches of rainfall	4.04	4.12	1.71	3.02	2.67	3.44	3.82	4.55	4.00	1.01	2.14	2.28	36.80
Inches flowing off	3.18	3.41	1.22	2.20	1.96	1.34	.84	.53	.42	.29	.27	.37	16.01
Flow in thousand gallons daily per square mile	1,780	1,910	731	1,230	1,135	750	487	297	235	168	151	214	762
Horse-power on one foot fall per square mile	.314	.337	.128	.217	.199	.132	.084	.052	.041	.030	.027	.038	.134

DRIEST PERIOD.

	December.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	Year.
Inches of rainfall	4.05	3.66	4.76	3.83	.61	2.71	3.87	.96	1.18	.94	3.04	2.02	31.63
Inches flowing off	3.18	2.99	3.94	2.93	1.30	.58	.47	.24	.16	.15	.15	.16	16.25
Flow in thousand gallons daily per square mile	1,780	1,670	2,355	1,645	754	325	272	134	89	87	84	93	775
Horse-power on one foot fall per square mile	.314	.295	.415	.290	.133	.057	.048	.024	.016	.015	.015	.016	.136
Continued.													
Inches of rainfall	2.63	4.57	4.22	3.57	2.12	5.06	1.90	1.37	6.40	12.09	1.32	.99	46.24
Inches flowing off	.19	.46	2.88	2.69	1.79	1.57	.85	.24	.22	4.73	1.50	.74	17.86

For Highland headwaters use Table No. 51. Not over 12 inches per annum could be safely collected on this water-shed as a whole, or 570,938 gallons daily per square mile, and this will require storage amounting to 6.34 inches upon the water-shed, or 110,200,000 gallons per square mile. Such reservoirs would be drawn down 16 months. During 9 months of an ordinary dry year, the power from this water-shed will amount to .041 horse-power per foot fall per square mile, or a little less than upon the Passaic.

TABLE No. 56.

Estimated Flow of Small Red Sandstone Water-Sheds Free from Sands and Gravel (Unglaciated).

AVERAGE YEAR.

	December.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	Year.
Inches of rainfall	3.72	3.63	3.45	3.72	3.63	4.04	4.04	4.23	4.59	3.72	3.45	3.72	45.94
Inches flowing off	2.89	2.97	2.78	2.83	2.34	1.51	.85	.40	.33	.58	1.60	2.64	21.72
Flow in thousand gallons daily per square mile	1,620	1,660	1,665	1,585	1,355	890	493	224	185	336	895	1,530	1,030
Horse-power on one foot fall per square mile	.285	.293	.295	.279	.239	.149	.087	.039	.033	.059	.158	.270	.182

ORDINARY DRY YEAR.

	December.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	Year.
Inches of rainfall	4.04	4.12	1.71	3.02	2.67	3.44	3.82	4.55	4.00	1.01	2.14	2.28	36.80
Inches flowing off	3.18	3.41	1.22	2.20	1.65	1.10	64	.37	.28	.12	·10	.38	14.65
Flow in thousand gallons daily per square mile	1,780	1,910	731	1,230	955	603	371	207	157	69	56	220	698
Horse-power on one foot fall per square mile	.314	.337	.128	.217	.168	.108	.065	.036	.028	.012	.010	.039	.123

DRIEST PERIOD.

	December.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	Year.
Inches of rainfall	4.05	3.66	4.76	3.83	.61	2.71	3.87	.96	1.18	.94	3.04	2.02	31.63
Inches flowing off	3.18	2.99	3.94	2.93	1.09	.26	.24	.04	.04	.04	.04	.04	14.83
Flow in thousand gallons daily per square mile	1,780	1,910	2,355	1,230	631	145	139	22	22	23	22	23	706
Horse-power on one foot fall per square mile	.314	.295	.415	.290	.111	.026	.024	.004	.004	.004	.004	.004	.124
Continued.													
Inches of rainfall	2.63	4.57	4.22	3.57	2.12	5.06	1.90	1.37	6.40	12.09	1.32	.99	46.24
Inches flowing off	.04	1.44	3.46	2.69	1.40	1.63	.54	.04	.04	5.75	1.03	.50	18.56

Upon these water-sheds 7.26 inches storage, or 126,161,000 gallons per square mile, would be needed to utilize 12 inches per annum, or 570,938 gallons daily per square mile. The reservoirs would not be full for 16 months. During 9 months of an ordinary dry year the available horse-power will be .028 horse-power per foot fall per square mile, about two-thirds that of the Passaic and two-fifths of that of the Highland water-sheds.

HACKENSACK RIVER.

The Hackensack rises near Haverstraw, in Rockland county, New York, and flows due south, emptying into the head of Newark bay, about 34 miles, in a direct line, from the source. The total area drained is 201.6 square miles, of which 64.1 lies in the State of New York. The river is tidal and navigable to New Milford, 20 miles from the mouth. The lower part of the water-shed is occupied by tidal meadows 4 miles wide by 10 miles long, and having an area of 19,846 acres. These meadows are generally only two or three inches above the level of high tide. They occupy the entire width of the lower water-shed, excepting less than a mile on either border. Above the head of tide at New Milford the water-shed includes 114.8 square miles, and of this about 60 per cent. is in forest. By the census of 1880, the population was 216 to the square mile for the whole water-shed, and 125 for the portion above New Milford. This is a suburban population distributed in a number of small villages, and is steadily increasing. The water-shed is heavily covered with drift, sand and gravel, especially in the flatter portions of the valley. There is also a little marshy land near the streams, including about 3 per cent. of the whole area. The only natural lake of any size is Rockland lake, in New York, within half a mile of Hudson river. It is 1.75 miles wide by 2 miles long. There are quite a number of good-sized mill-ponds along the stream and its branches. The general elevation of the water-shed ranges from 0 to 400, and averages about 200 feet. A trap ridge forms the eastern and northern boundary, and throughout the entire distance from Jersey City to Haverstraw, the Hackensack drainage extends to within half a mile of the west bank of Hudson river. The accompanying table of gaugings has been compiled from data furnished by Charles B. Brush, C.E., and from rainfall records of the United States Weather Service:

FLOW OF HACKENSACK RIVER AT NEW MILFORD.

Drainage area, 114.8 square miles.

MONTH.	Rain—Inches.	Flow—Inches.	FLOW IN CUBIC FEET PER SECOND.		
			Greatest.	Least.	Average.
1890.					
January	2.89	3.03	535	303	302
February	4.97	3.35	736	248	357
March	6.81	5,05	950	305	503
April	2.62	3.62	765	252	372
May	4.62	3.11	563	48	360
June	5.03	1.96	472	118	202
July	5.71	1.29	302	48	129
August	4,72	1.22	256	22	120
September	4.33	1.66	355	57	186
October	7.36	2.87	535	113	287
November	.79	2.03	208	160	207
December	3.94	2 50	665	155	247
1891.					
January	7.65	5.30	1,990	163	522
February	4.31	5.17	815	302	556
March	4.28	4.33	1,100	251	446
April	2.21	2.66	534	119	263
May	2.75	1.42	347	87	139
June	1.95	.87	163	33	85
July	4.08	.72	206	33	70
August	3.54	.66	208	26	62
September	2.42	.80	208	26	79
October	2.36	.56	116	31	59
November	2.76	.96	203	51	94
December	4.59	1.49	359	34	150
1892.					
January	5.34	3.52	....	....	....
February	1.38	1.80	....	....	....
March	3.21	2.60	....	....	....
April	1.81	1.70	....	....	....
May	4.99	1.87	....	....	....

	Rain—Inches.	Flow—Inches.
January, 1890, to December, 1890	53.79	31.69
June 1890, to May, 1891	53.08	32.41
December, 1890, to November, 1891	41.86	25.95
June, 1891, to May, 1892	38.43	17.55
Year ending October, 1884	44.84	18.31
Year ending October, 1885	41.70	24.36
Year ending October, 1886	44	17.58
Year ending October, 1887	48.09	19.41
Year ending October, 1888	52.52	32.25
Year ending October, 1889	57.74	21.64
Year ending May, 1891	53.08	32.41
May, 1892	38.43	17.55

Average excess of evaporation over that given by the Passaic formula (E equals 15.50 plus 0.16 R) is 3.8 per cent.

We have no observations of maximum flow, but the following shows how the highest observed summer and winter maxima compared with those upon the Raritan, Ramapo and Passaic at the same time.

MAXIMUM FLOW IN CUBIC FEET PER SECOND PER SQUARE MILE.

	May, 1890.	October, 1890.	January, 1891.
Hackensack	4.9	4.7	17.3
Raritan	4.6	8.1	27
Ramapo	4.8	5.2	28.5
Passaic	3.6	4.1	12.4

The January flow is seen to be larger than the Passaic, but this may only mean that, because of the higher temperature, the snow and ice were melting more rapidly upon the Hackensack. The comparison with the Raritan is fairer, and shows considerably less flow. The summer maxima did not differ much from the Raritan and Ramapo. It is not probable that the maximum flood-flow on the lower part of the water-shed exceeds 40 cubic feet per second per square mile. The minimum shown in the above table is 0.19 cubic feet per second per square mile. This was for a single day, and may easily have been due to the holding back of water in some of the mill-ponds. It does not appear probable, from a study of the records, that the natural flow falls much below 0.25 cubic feet per second per square mile. The ground-water curve, shown in Plate VI., was deduced from these gaugings, and shows a high rate of flow, decreasing quite rapidly, however, at times of extreme depletion of the ground-water. It is probable that this rapid decrease takes place at about the time that the ground-water becomes nearly exhausted from the beds of gravel. The ground-flow appears to be very similar to that shown by the higher water-sheds of southern New Jersey, such as the Batsto. Table No. 54 is based upon this stream, and is especially applicable.

Water-supply.—The Hackensack Water Company, Re-organized, supplies Hoboken, Hackensack, and several other towns from this stream by pumping at New Milford. The storage is only trifling in amount, excepting as that afforded by the chain of mill-ponds above is available. This company reports an average draught of 6,900,000 gallons daily. At 0.25 cubic feet per second per square mile the minimum yield of the stream at New Milford, flowing naturally, would be 18,600,000 gallons daily. With storage equal to 4.91 inches on the water-shed, the available supply would be 65,600,000 gallons daily. Sites for this storage could probably be found without difficulty upon the water-shed. The water is aërated before using. The stream is said not to get as muddy as other red sandstone streams.

Water-power.—The Hackensack is considerably used for water-power, but the fall along the stream is quite moderate. It has the reputation of being very steady during dry weather, with a well-sustained flow. We estimate the power at New Milford at 8.4 horse-power per foot fall during 9 months of the ordinary dry year. Pascack creek, the largest tributary, drains 28 square miles, and the Hackensack, above the junction with the Pascack, 58 square miles. At Harrington Park the available power is 4.2 horse-power per foot fall, at Rivervale 3.8 horse-power, and from 8 to 12 horse-power is improved at these points, the pondage being good. The Pascack at Hopper's mill, at Westwood, gives 1.97 horse-power per foot fall. Musquapsink creek drains 7 square miles, and above this branch the power of Pascack creek is 1.46 horse-power per foot fall. These water-powers on the Hackensack are, some of them, probably nearly two centuries old, having been developed for saw and grist mills at an early date.

Drainage works—Some attempts have been made in the past to reclaim the tidal meadows on the lower Hackensack. Four thousand and forty-five acres, bounded by Passaic river, the Hackensack and Saw-mill creek, were embanked and partially improved by the New Jersey Land Reclamation Company about 1869, but the undertaking seems to have been abandoned. A very small amount of drainage is received by these meadows from the bordering upland, and the water to be removed would be practically only what falls upon the meadows themselves less evaporation. The conditions seem to be favorable to their improvement, and if the soil should be found adapted to market-gardening, they would become valuable because of their nearness to markets. The results of a survey of these meadows will be found in the annual report of 1869. These surveys show that from about the line of the Newark turnpike northward to Saw-mill creek most of the area was an old cedar swamp bottom, and this extends in a narrow strip through the center of the meadow to a point near Berry's creek, about three-quarters of a mile above its mouth. The rest of the underlying material is mainly blue mud, some of which includes peat, and the prevailing depth of the mud is about 10 feet, but in places it is more than twice this. The marsh was sounded to these depths by a slender iron rod, usually put down by the strength of one man, but sometimes requiring two, indicating generally a not very firm material. It was concluded at that time by the late Dr. George H. Cook that the difficulties to be encountered in the drainage of these meadows were much less than those met with in Salem county, where very considerable areas have been successfully reclaimed.

The smaller fresh-water marshes above New Milford seem to be due mainly to a lack of fall from the edge of the marsh into the stream. As these are in the midst of a fine residence district, their drainage is to be desired as a sanitary measure. Those at Closter, for instance, on the Tienekill, have a fall along the stream of ten feet in one and one-half miles, and their drainage would seem to be merely a matter of clearing out and deepening stream channels. In all such drainage works, where marshes are bordered by banks of gravel discharging large amounts of ground-water, provision should be made to intercept these waters by drains along the foot of the bank conveying the water directly into the main channel. The saturation of many marshy areas is due mainly to this free discharge of ground-water into the marsh along its whole border. There being no channel for such water to reach the stream, the marsh becomes saturated with the water seeking an outlet.

ELIZABETH RIVER.

This stream rises in the city of East Orange. It is tidal to Elizabeth and navigable for small craft. Above Elizabeth the area of the water-shed is 19.4 square miles, and it is heavily covered with drift, especially about Salem and Union. The stream is of comparatively little importance, excepting that it is used as a source of water-supply for the city of Elizabeth. Table No. 54 is applicable to the flow of this stream. It shows the capacity of the stream in the driest months, without storage, to be 2,386,200 gallons daily. Elizabeth at present uses 3,500,000 gallons daily, but a portion of this has recently been drawn from the wells at Netherwood. In 1890 the average consumption of water was reported to be 2,500,000 gallons daily, and this was drawn entirely from Elizabeth river. There is a small amount of storage at Lake Ursino, which is the reservoir of the water works, and in the mill-ponds above, so that this amount was probably readily obtained.

We estimate the power at Salem at 0.95 horse-power per foot fall. The pondage here and above makes the 2.2 horse-power used by the mill there always available during working hours.

RAHWAY RIVER.

The east branch of the Rahway rises in the city of Orange and the west branch between First and Second mountains, and the general course of the river is southward. From the source to the mouth is about 16 miles in a direct line. The river is navigable to Rahway, which is the head of tide, about 9 miles from the mouth. The Rahway proper drains 41 square miles, and its principal branch, Robinson's brook, drains 22.8 square miles, making 63.8 square miles for the total water-shed above Rahway. The water-shed has a large and rapidly-increasing population. It is generally well covered with glacial drift. Our observations indicate a minimum flow of 0.2 cubic foot per second per square mile. The maximum probably ranges somewhere between 40 and 50 cubic feet per second per square mile.

Water-supply.—On the west branch of the Rahway the city of Orange has a storage reservoir between First and Second mountains having a capacity of 375,000,000 gallons. The dam is an earthen embankment with a masonry heart-wall, and is 875 feet long by 40 feet high. The drainage area tributary to this reservoir is 5 square miles in extent. The area of the reservoir is 64 acres. The storage amounts to 4.5 inches on the water-shed, and as this reservoir has steeper slopes and less drift than the main river, Table No. 55 is applicable. We find that this reservoir will furnish, in the driest period, 2,200,000 gallons daily.

The city of Rahway is supplied from Rahway river at a point just above the town, by pumping, without storage. We estimate the minimum flow of the river at this point to be 5,297,000 gallons daily. This water is said to be naturally very satisfactory, and appears to be very pure. The population is increasing very rapidly upon the water-shed, and the lower part of the stream is not likely to be further utilized as a source of water-supply. Some of the smaller communities in this thickly-settled portion of the State might possibly find it well worth while to consider the plan of owning outright a small gathering-ground which they could effectually protect from contamination in the future. Such a plan, where a suitable location is to be had close at hand, may be considerably cheaper than going to a distance, and offers greater security against pollution. Some of the small branches of the Rahway might be utilized in this way, and in fact many of the smaller water-sheds which are largely covered with drift would be suitable for such use, as such land is usually of little value where it is not becoming a residence section. As instances, we may call attention to Normahiggin brook, at Branchville, having about 2 square miles of drainage area, which would supply, with storage, 1,140,000 gallons daily. The headwaters of the south branch of the Rahway above Iselin embrace an area of 7 square miles, with an ultimate capacity, with storage, of 3,997,000 gallons daily. Both of these areas have quite a large proportion of forest.

Water-power.—At the lowest mill site on the Rahway 2.9 horse-power per foot fall is available for continuous power, and this site with 10 feet fall is not at present occupied. The succession of ponds above would make this practically 6 horse-power for working hours, or 60 horse-power for this mill site. At Cranford we estimate 2.7 horse-power available. From 5.5 to 6 horse-power per foot fall is in use between these ponds during working hours. Robinson's branch, at Rahway, will furnish 1.6 horse-power per foot fall during 9 months of the ordinary dry year, and the mill here uses about 2 horse-power.

RARITAN RIVER.

The total area of the water-shed of this stream is 1,105.3 square miles. It is the largest stream of the State, excepting the Delaware, but is not nearly so important as the Passaic, from the fact that no considerable portions of the waters are united into one channel until they are within 7 miles of the head of tide-water, and but 17 feet above sea-level. The Passaic at Little Falls unites the drainage of 772.9 square miles at an elevation of 158 feet, while the Raritan, at Raritan, has but 468 square miles, at an elevation of 49 feet, and Bound Brook 875 square miles, at an elevation of 17 feet. Nevertheless, the Raritan basin is a productive agricultural section, and a large amount of water-power is utilized along the various branches.

The flood-flows have a peculiar interest because of the populous and highly-cultivated condition of the valleys, which renders them more destructive, and consequently makes a knowledge of the laws governing them more essential.

The water-shed is fully described in the physical description of the State, and its character is better shown by a study of the topographic maps than it can possibly be by any written explanation. A few facts not so apparent may be pointed out, however, in discussing its flow. There is little ground-storage anywhere on the water-shed, excepting on the Millstone, part of which is a sand-hill stream, with some of the characteristics of southern New Jersey streams; but enough of the area is on steep trap and red sandstone slopes to give even this branch a pretty high rate of flood-flow. Only 13 per cent. of the shed is in forest. Of the 879 square miles above the point of gauging, about 150 square miles area is on a highly-cultivated part of the Highlands and on the trap ridges; about 98 square miles, including the water-shed of the upper Millstone, is on the flat clay and marl district, and the remainder on the low, level, red sandstone plain.

The central portion of this water-shed is highly cultivated, and quite large areas are almost entirely deforested. The forested portions, which are embraced in the 13 per cent. above noted, lie largely upon the trap ridges. The river is tidal to a point about 2 miles above New Brunswick and is navigable to that city, distant about 12 miles from the mouth. This part of the river has been improved by the United States government. The depth of water to New Brunswick is about 10 feet at mean tide. South river, a branch of the Raritan, from the south, about 7 miles above its mouth, is also navigable to Old Bridge. The table of gaugings accompanying are the results of a record kept at the Delaware and Raritan canal dam, about 5 miles above New Brunswick, by William Fisher:

FLOW OF THE RARITAN AT BOUND BROOK, 1890-3.

Drainage area, 879.0 square miles.

MONTH.	Rain—Inches.	Flow—Inches.	FLOW IN CUBIC FEET PER SECOND.		
			Greatest.	Least.	Average.
1890.					
February 17th to 28th	1.58	.98	2,772	1,406	1,938
March	6.26	6.13	17,818	872	4,727
April	2.74	2.26	3,265	874	1,773
May	4.95	1.95	4,060	752	1,489
June	3.97	1.32	2,824	462	1,040
July	5.68	1.18	2,022	498	898
August	5.18	1.58	3,405	498	1,205
September	4.31	1.34	2,823	493	1,064
October	6.74	3.06	7,133	859	2,360
November	.88	1.30	1,779	781	1,016
December	3.55	2.16	7,526	462	1,654
1891.					
January	7.06	4.92	23,746	420	3,738
February	4.21	3.47	6,056	1,295	2,931
March	4.64	4.47	10,142	1,386	3,404
April	1.83	1.62	3,439	512	1,276
May	2.70	.59	735	245	450
June	1.75	.24	509	113	189
July	3.92	.28	326	180	213
August	6.58	.94	5,804	148	716
September	1.72	.86	2,564	253	678
October	2.68	.43	804	208	328
November	2.21	.54	1,174	201	426
December	4.74	2.36	8,215	292	1,798
1892.					
January	5.58	4.57	22,760	990	3,482
February	1.19	1.31	5,182	720	1,066
March	3.98	2.59	7,941	795	1,974
April	2.02	1.25	1,893	677	985
May	4.62	1.47	3,177	513	1,120
June	4.06	1.60	10,927	443	1,261
July	4.11	.57	2,764	180	434
August	3.61	.47	2,201	180	358
September	2.75	.31	711	180	244
October	.32	.24	201	122	183
November	6.99	2.18	20,698	122	1,718
December	1.68	1.29	2,610	609	983

FLOW OF THE RARITAN AT BOUND BROOK, 1890-3—Continued.

Drainage area, 879.0 square miles.

MONTH.	Flow—Inches.	Rain—Inches.	FLOW IN CUBIC FEET PER SECOND.		
			Greatest.	Least.	Average.
1893.					
January	3.39	2.11	12,514	720	1,608
February	6.23	4.16	15,772	1,228	3,494
March	3.41	5.27	19,125	878	4,016
April	4.65	4.00	10,091	918	3,152
May	4.28	3.30	10,987	387	1,515
June	3.57	.64	2,130	180	504
July	3.14	.43	820	180	328
August	8.27	1.45	5,893	180	1,105
September	3.60	.71	3,284	157	559
October	3.86	.95	4,494	180	724
November	3.59	1.50	7,352	291	1,190
December	3.12	2.63	5,698	180	2,004

	Rain—Inches.	Flow—Inches.
June to November, 1890	26.76	9.78
December to May, 1891	23.99	17.23
June to November, 1891	18.86	3.29
Year 1890-1.	42.85	20.52
December to May, 1892	22.13	13.55
June to November, 1892	21.84	5.37
Year 1891-2	43.97	18.92
December to May, 1893	23.64	20.13
June to November, 1893	26.03	5.68
Year 1892-3	49.67	25.81

NUMBER OF DAYS THE RARITAN STOOD AT GIVEN STAGES DURING 1,414 DAYS.

	Above.	Above.	Above.	Above.	Above.	Above.	Above.
Flow in inches on water-shed in 24 hours............	.125	.100	.075	.050	.025	.015	.14
Flow in inches per month.........	3.81	3.05	2.28	1.52	.76	.46	.42
Flow in cubic feet per second per square mile.....................	3.35	2.69	2.02	1.34	.67	.40	.35
1890, 318 days.......................	33	62	106	163	273	318	318
1891.................................	56	66	88	113	169	220	247
1892.................................	19	30	46	89	235	252	252
1893.................................	43	63	121	167	240	264	271
Averages *......................	39	57	94	139	239	275	284
Passaic averages—same years.....	53	86	120	174	249	290	....

* In making up these averages the figures for 1890 have been increased 15 per cent. to make them approximately correct for a full year.

Table No. 55 of flow is based on the Raritan, and applies especially to this stream. In the above table showing the stages of the Raritan, the last column will be seen to correspond to the monthly flow available during 9 months of the ordinary dry year, as shown in Table No. 55. The previous column corresponds to the same figures for the Passaic as shown by Table No. 53, and it will be noted that during these two years the actual number of days at which the Raritan stood above this stage agrees closely with the number of days that the Passaic stood above its corresponding stage. Our 17 years' record on the Passaic showed that, taking the flow by days, the flow available for 9 months of an ordinary dry year, as computed by us, was really available for 9 months in the year on an average throughout the whole period. The above-noted resemblance shows that the Raritan also, when taken by days, gives the available flow for 9 months of an ordinary dry year on an average 9 months in the year. On these tables, and similar tables for other streams, we have based our conclusions that our estimated available horse-power is really available on an average 9 months in the year. It will be noted that this does not agree exactly with our computed flow for an average year, which shows the flow for 9 months somewhat in excess of the flow for 9 months of an ordinary dry year. The reason of this is that the average year, as we have previously remarked, is not a natural year, but it really eliminates the dry period which is almost sure to occur during some part of every year.

The minimum flow of the Raritan was observed by the late Ashbel Welch, C.E., at the Delaware and Raritan canal dam, during a very dry time, to be 180 cubic feet per second. Our table above shows a minimum of 122 cubic feet per second, which is at the rate of 0.14 cubic feet per second per square mile, and this, we have reason to believe, is pretty close to the absolute minimum for 24 hours.

The flood discharge of the Raritan is at a very high rate, and the stream is a fluctuating one. This is no doubt partly chargeable to deforestation, but the lack of gravels and sand upon the water-shed, and the consequent small ground-storage, also contribute. The shape of the water-shed, too, has a good deal to do with this result. This is such that all the upper branches focus at a point near Bound Brook and discharge their flood-flows almost simultaneously, instead of delivering one at a time, as is the case of long, narrow water-sheds when the branches are pretty evenly distributed along the main stream. The following table of floods which occurred during four years covered by the gaugings gives a good indication of their frequency. The river is just about bank-full at 7,000 cubic feet per second discharge at the point of gauging, and nothing less than 8,000 cubic feet per second would be regarded as really a freshet:

FLOODS ON THE RARITAN OVER BANK-FULL FROM 1890 TO 1893—FOUR YEARS.

Date.	Maximum Cubic Feet per Second.	Duration.
March 23d, 1890	17,818	5 days.
October 24th, 1890	7,133	1 day.
December 18th, 1890	7,526	1 day.
January 12th, 1891	16,167	1 day.
January 23d, 1891	23,746	1 day.
March 10th, 1891	10,142	1 day.
March 13th, 1891	7,895	1 day.
March 24th, 1891	7,131	1 day.
December 25th, 1891	7,654	1 day.
January 3d, 1892	22,760	1 day.
January 14th, 1892	12,514	2 days.
January 19th, 1892	7,126	1 day.
June 10th, 1892	10,927	1 day.
November 16th, 1892	20,698	2 days.

Date.	Maximum Cubic Feet per Second.	Duration.
January 2d, 1893	12,514	2 days.
April 15th, 1893	8,448	1 day.
April 21st, 1893	10,091	2 days.
May 4th, 1893	10,987	3 days.
November 5th, 1893	7,352	1 day.
December 4th, 1893	7,166	1 day.

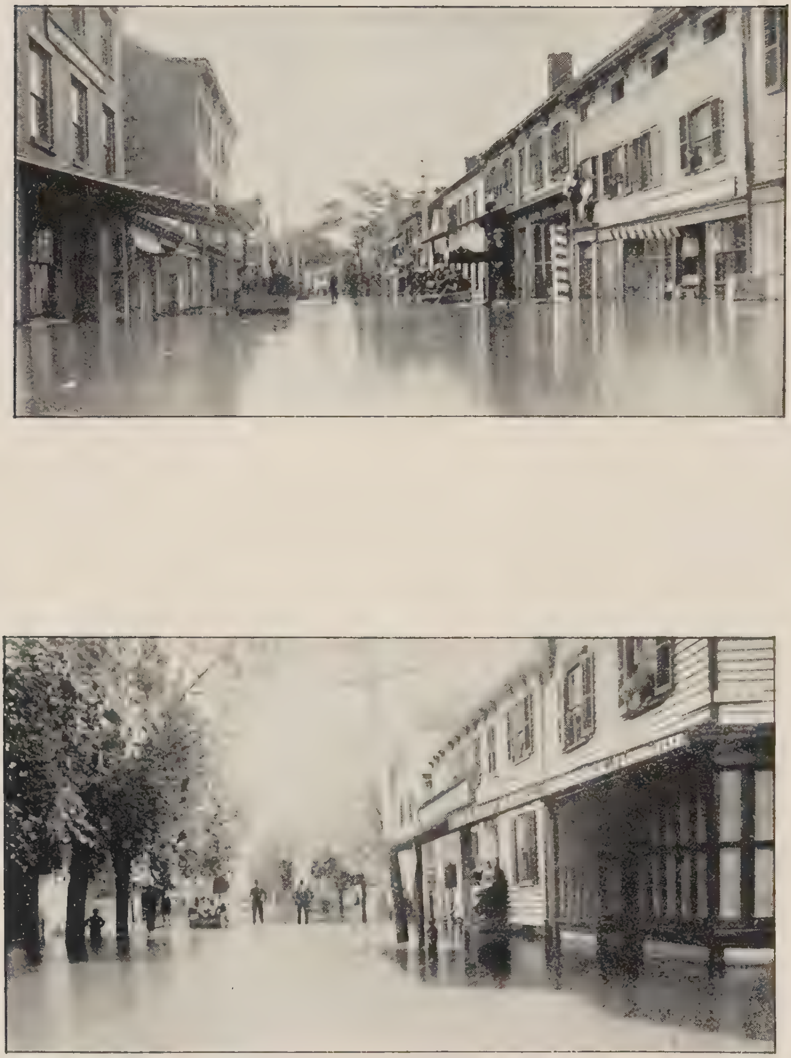
Taking floods over 8,000 cubic feet per second in the above list, which happens to be the same minimum used for the table of floods on the Passaic on a slightly smaller water-shed, we find in all 13 floods during 4 years, one ranging as high as 23,746 cubic feet per second. During the same period there were but 5 on the Passaic, and the highest of these had a maximum discharge of 11,701 cubic feet per second. As the total discharge of the Raritan in inches on its water-shed during this period was less than that of the Passaic, this gives a good illustration of the fluctuating character of the flow from the Raritan water-shed. The following supplementary table gives the list of floods from 1873 up to the beginning of our gaugings, mostly collected by Mr. D. H. McLaury, of New Brunswick, and although not complete, gives some assistance in forming an idea of their frequency and relative height for recent years. Heights are given above high-tide mark at Albany street bridge, or in some cases at the Raritan Landing bridge, and some idea of the corresponding rise above may be gained from the rise in 1882, which was 12 feet at New Brunswick, 13 feet at Raritan Landing, 14.2 feet on the canal dam, and about 16 feet at Bound Brook. A rise of 13 feet at Raritan Landing corresponds to a flow of 52,000 cubic feet per second, of 8 feet to 24,000 cubic feet per second, of 7 feet to 18,000 cubic feet per second, and of 4 feet to 7,500 cubic feet per second. The rise at New Brunswick is, at the most, one foot less, ranging down to about the same at lower stages:

FLOODS ON THE RARITAN AT NEW BRUNSWICK.

Date.		Height in Feet.	Remarks.
July	30, 1873	4.25	Rain, 5.94 inches, from 27th to 29th.
August	14, 1873	4.50	5.29 inches rain, on 14th.
September	18, 1874	9.00	7.10 inches, from 15th to 18th.
March	26, 1876	6.00	3.33 inches, on 25th and 26th.
September	18, 1876	5.00	2.57 inches, on 17th, after wet period.

Date.	Height in Feet.	Remarks.
October 5, 1877	6.50	4.30 inches rain, on 4th and 5th, after a month of dry weather.
September 24, 1882	12.00	Rain, 11.84 inches in 4 days. No greater freshet during the century.
August 4, 1885	3.75	Rain, 3.30 inches, on the 3d.
February 12, 1886	9.00	Rain, 2.5 inches, with melting snow and ice.
January 15, 1887	3.75	Rain of 1 inch; thaw and break-up of river.
February 19, 1887	——	Over banks; rain, 1.52 inches, and thaw.
July 23, 1887	8.00	Rise at Raritan Landing; rose rapidly at midnight; 1.43 inches rain after a wet period.
August 2, 1887	4.00	After 6 weeks of very sultry weather, a shower of 4.62 inches in 1 hour and 15 minutes.
January 2, 1888	6.00	From December 28th to January 1st, 3.82 inches rain, with melting snow and ice.
February 25, 1888	——	Over banks; rain, 1.60 inches, and thaw.
July 5, 1888	3.50	Heavy shower.
September 20, 1888	(?)	A flood; no record of height.
December 18, 1888	4.00	Rain of 3 inches, on 17th.
January 7, 1889	4.00	Rain, 1.82 inches, on 6th, with thaw.
April 28, 1889	(?)	Rain, 3.67 inches, 26th to 28th.
June 1, 1889	4.20	Rain, 2.20 inches, May 26th to June 1st.
August 15, 1889	5.50	Showers of 2.56 inches, following wet period.
November 28, 1889	8.00	Rise at Raritan Landing. Rain of 2.54 inches, 27th to 28th, following.

There have been three great floods on this river during the century, completely throwing into the background scores of other freshets which would otherwise be considered heavy. The first occurred November 24th, 1810, the second July 17th, 1865, and the third September 24th, 1882. Of the last, I have been able, by careful inquiry, to obtain fair measurements at the Bound Brook dam. It began to rise about 3 P. M. of the 22d, had covered the canal bank at the dam, 11.5 feet above the crest, Saturday, at 3 P. M., and reached a height of 14.2 feet above the crest at 5 A. M. of Sunday, the 24th, when it was at its maximum, falling within the river banks again by 7 A. M. of Monday. The overfall at the dam was drowned, so that the head for computation is reduced to 12.7 feet, and conditions were such that the safest computation is that for a free overfall with this head. This gives the following rates of flow, bank-full of the river at this point having been ascertained to be a flow of 7,000 cubic feet per second.



STREET SCENES IN NEW BRUNSWICK.

Freshet on the Raritan, September 24th, 1882.

September 22d, 3 P. M.	7,000	cubic feet per second.
" 23d, 3 P. M.	35,500	" " " "
" 24th, 5 A. M.	52,000	" " " "
" 25th, 7 A. M.	7,000	" " " "

This gives a total discharge for these 64 hours of 6,489,000,000 cubic feet, or 3.36 inches on the water-shed. This amount of water would cover Middlesex county 10 inches in depth. It is at the rate of 59.3 cubic feet per second per square mile maximum discharge.

There was a break in the canal at Bound Brook during this flood, but the effect of this would be so trifling on the general result, or even the maximum discharge, that it may safely be neglected. We noted, in our discussion of this flood on the Passaic, that the total discharge amounted to 3.13 inches on the water-shed. The above shows almost the same total amount discharged. In our estimate of flow during the second year of the driest period in Table No. 55, the cause of this great flood is well shown, although the rainfall there given is not exactly as it occurred on the Raritan water-shed. It is so similar, however, that it is not necessary for us to make a special computation for the Raritan. From April to August, inclusive, the total evaporation, as shown in Table No. 46b, had been 16.85 inches, and the total flow, as shown by Table No. 55, 4.67 inches, making a total draught upon the water-shed of 21.52 inches, whereas the rainfall had only been 15.29 inches, and the difference of 6.23 inches had been drawn from the ground-water. This went on increasing until just before the storm which caused the flood, and when the heavy fall of 12 inches came it was sufficient to make good this depletion of ground-water and still leave 4.73 inches upon the water-shed of surplus to flow off. The ground having taken up all that it could, this surplus rushed into the streams and caused the greatest flood of the century.

The flood of 1865 occurred on July 17th. The cause of this flood does not appear directly in the rainfall record at New Brunswick, but we find that the ground had been continuously full of water up to this date, and it is mentioned that heavy thunder showers occurred, beginning at 5 P. M. on the 16th. Taking the average of the monthly rainfall at Paterson, Newark, New York and New Brunswick, the total flow-off for the month of July would have been 2.18 inches on the water-shed. There is evidence in some of these records that the showers spoken of were very much heavier on the upper water-shed than they were at New Brunswick, and such heavy showers, falling on the surface when it was already full of water, were undoubtedly the cause of this flood. It rose with great rapidity, reported to have been at one time at the rate of 6 inches in about five minutes at Bound Brook. This would indicate the presence of a flood-wave at that time moving down the valley.

The late Mr. Lawrence Vanderveer informed me that it was reported that in 1810 heavy rains began on the 9th of November, continuing at intervals until the 24th, when the flood reached its height.

We have been at some pains to establish the relative height of these three great floods in 1810, 1865 and 1882 to see if any increase in the maximum flood-discharge could be discovered. Mr. John D. Field, of New Brunswick, saw the freshet of 1810, and was fully familiar with the flood-marks along the river. He is of the opinion that it was probably equaled by the later floods, but never exceeded. Mr. D. F. Vermeule is also familiar with the lower part of the river, and thinks that the flood of 1865 was not so high as that of 1882. Mr. Lewis D. Clark, at Bound Brook, has marked most of the high freshets, and says the freshet of 1882 was 2 feet higher at his house on the river bank than that of 1865. The total rise here in 1865 was 16 feet. He also thinks that the freshet of 1810 was 3 feet lower than that of 1882. Others give the difference to be from 10 inches to 3 feet, but at the greater figure it would be fully accounted for by the building of the dam below, in 1833, which caused a difference of 5.5 feet in the height of the river immediately at its site, raised the ordinary level a foot or two at Bound Brook, and restricted the flood outlet to the opening between its high abutments at the river banks. Mr. Lawrence Vanderveer, of Griggstown, says that the water was 2 feet higher at the mouth of Beden's brook in 1882 than it was in 1810, from known marks of the early freshet; but this may also be due to the dam at Bound Brook. Altogether the weight of evidence is to the effect that the floods of 1810 and 1882 were of about equal volume, and the flood of 1865 was somewhat below the others. It is well established that there were no others nearly so high in the intervals, although there was a high one at the time of building the dam in 1832 or 1833, and others in 1836 or 1837 and 1858.

In the weather record kept by the late P. V. D. Spader, Esq., at New Brunswick, extending from 1847 to 1890, the freshets of 1865 and 1882 are mentioned, the former being noted to be the "greatest since 1810."

Water supply.—The Raritan carries a large amount of red mud when it is swollen. It would require settlement, and possibly filtration, before being suitable for public water-supply. Otherwise it does not seem to be a bad water, judging from the results of our chemical analysis. Above the canal dam to which we have referred, it would always be possible to draw 180 cubic feet per second with the present pondage. This amounts to 116,329,000 gallons daily. At Raritan we estimate the dry-season flow to be 42,330,000 gallons daily. The water is pumped at this point to supply Somerville and Raritan, the present use being reported at 800,000 gallons daily. Water-power is used for pumping. This water is filtered.

Water-power.—At the head of tide at Raritan Landing there was formerly a dam across the river and a mill site. This was destroyed by the construction of the Delaware and Raritan canal, and the company substituted for it the right to 200 horse-power to be drawn from the canal under about 14 feet head. This would amount to 126 cubic feet per second. The Norfolk and New Brunswick Hosiery Company are said to be entitled to the use of about 60 cubic feet per second from the canal. This is used on about 11 feet fall. The wheels in place there, as reported, would call for about 176 cubic feet per second. Our gaugings show, during the daytime, a flow of 254 cubic feet per second through the canal, and an average flow of about 180 cubic feet. We estimate about 45 to be needed for leakage and lockage over and above the amount of lockage from the upper level of the canal. This would leave 135 cubic feet per second continuously available for power, equal to 15.34 horse-power per foot fall, and if used with the full 17 feet head available at New Brunswick would give 260 horse-power. We estimate the power available for 9 months of the ordinary dry year to be 36 horse-power per foot fall. Allowing for leakage and lockage, if this amount could be passed throughout the canal to New Brunswick, it would give, on 15 feet fall, 465 horse-power, or twice this for 12 hours per day.

At Raritan we estimate 19.2 horse-power per foot fall, and we find 20.2 horse-power improved at the Raritan Water Power Company's plànt. This consists of a crib dam 240 feet long by 4 feet high, and a raceway 3 miles long built about 1840. The fall is about 15 feet. The rental is somewhat indefinite, but seems to approximate $28 per horse-power per annum. Between this and the mouth of the Millstone there is about 11 feet fall unimproved, with not very good opportunities for development.

MINOR BRANCHES OF THE RARITAN.

Mill brook enters the Raritan below New Brunswick, from the north. It has a drainage of 5.4 square miles, and its headwaters are in the glacial moraine. At Eggert's grist-mill, on this stream, the drainage area is but 3.5 square miles, and the fall about 20 feet. Our table would make the total available power for 9 months of the year only about 2.9 horse-power in all, or about 6 horse-power for working hours, but this mill appears to be able to do a large amount of work and keep one stone running a good deal of the time, so that it would appear that this stream has a larger flow than is shown by our estimate. This mill is not included in our canvass of water-power, its omission not having been noticed until after the printing of Appendix I.

Bound Brook has an area of 61.5 square miles, included in which is the city of Plainfield. It is made up of Ambrose's brook, Bound brook proper, and Green brook, which do not become one until within a short distance of their junction with the Raritan. Ambrose's brook has a water-shed of about 12 square miles, including an agricultural section of the red sandstone, with very little ground-storage. This stream belongs to the type, the flow of which is shown in Table 56. It has little value for either water-supply or water-power. Bound brook, above the mouth of Green brook, drains 24.4 square miles, and has a good deal of sand and gravel on its water-shed. To this Table No. 55 applies. At New Market we estimate the available power at 0.94 per foot fall, or about 2 horse-power for working hours. There is a grist-mill here with 8 feet fall. Green brook flows through the city of Plainfield. The western part of its water-shed is on the trap ridges known as First and Second mountains, and the eastern side contains a considerable sand area, which is quite flat, and on which the city of Plainfield is situated. Stony brook is a branch issuing from First mountain, west of Plainfield. To this Table No. 56 is applicable. This water-shed would be suitable for a gravity supply if it could be entirely protected from future contamination. It is adapted to become a gathering-ground for such a supply if its area can be owned outright, or otherwise controlled. At an elevation of 200 feet it has 5.2 square miles of water-shed. At the lowest monthly flow, which could be made available with very small storage, it will supply 114,400 gallons daily. With 7.26 inches storage it will supply 2,964,000 gallons daily. Blue brook, which issues from the mountain at Scotch Plains, is similar and has, above 210 feet elevation, 6.3 square miles of water-shed, and will supply 138,000 gallons daily at the least monthly flow, or 3,591,000 gallons daily with full storage. As we have mentioned in the case of some of the branches of the Rahway, the setting apart of such areas as this for gathering-grounds might be a practical solution of the difficulties of securing pure local supplies in this densely-populated northeastern section of the State.

Middle brook has a total area of drainage of 18.7 square miles. At a mill near the mouth it was stated that the power was available only one-quarter of the time during 3 months of the dry season of 1881. This indicates that during that time it did not exceed .008 horse-power per foot fall per square mile, which is a sufficient test of the applicability of Table No. 56. The village of Bound Brook is supplied from the east branch of this stream, the drainage area being about 10 square miles and the storage 10,700,000 gallons. By Table No. 56 we estimate that with this storage 1,850,000 gallons daily will be always available. With 7.26 inches storage, 5,709,000 gallons daily could be obtained. The elevation is about 175 feet. The other minor branches of the Raritan have no importance, and the larger ones we shall now consider separately.

SOUTH RIVER.

This is the lowest important tributary of the Raritan. It rises 7 miles southwest of Freehold, near the Ocean county line, at a point 20 miles due south from where it empties into the Raritan at Sayreville. It is tidal and navigable to Old Bridge and drains 132.8 square miles, receiving all of its affluents from the east. Twenty-five per cent. of the water-shed is in forest, and the population is 83 to the square mile. This is a sandy and gravelly water-shed with large ground-storage, and belongs to the southern New Jersey type of sand-hill streams. The curve of ground-flow used in computing Table No. 54 is applicable to such streams, and as the evaporation and rainfall resemble that of the red sandstone plain, this table may be used in computing the flow of South river.

Water-supply.—As a whole, this stream is not suitable as a source of public water-supply, but some of its minor branches may be excellent sources for local supply. Those which show a considerable outcropping of clay and marl, however, should be regarded with some suspicion, and carefully examined before adoption. The more sandy or gravelly water-sheds may furnish water of excellent quality.

Tennent's brook is one of these, and is now used to supply the city of Perth Amboy. The consumption is said to be 1,100,000 gallons daily. The water-shed is about 10 square miles, and there is sufficient storage to make the least monthly flow available, which would be equal to 1,230,000 gallons daily. With storage equal to one inch on the water-shed, 2,500,000 gallons daily, or, with 2 inches storage, 3,400,000 gallons daily would be available. It is doubtful if storage could be got to amount to the full 7.26 inches necessary to utilize 12 inches per annum.

Deep run, the next tributary south, has a drainage area of 15 square miles, generally similar to that of Tennent's brook, with somewhat better opportunities for storage. This would also be a good source of supply, and will furnish at the least monthly flow 1,845,000 gallons daily. With storage equal to 2 inches on the water-shed, 5,100,000 gallons daily may be obtained.

Manalapan creek, above Jamesburg pond, drains 27 square miles, and will furnish at the least monthly flow 3,300,000 gallons daily, or with storage equal to 2 inches on the water-shed, 9,100,000 gallons daily. This, while it may be satisfactory as a source of supply, would require somewhat closer scrutiny than the streams previously mentioned before adoption. On this South river water-shed, as on many others, the plan of selecting carefully from the smaller water-sheds and carefully watching and fully utilizing the same, is much preferable to drawing the supply from a larger stream, although thereby the expense of storage may be avoided.

Water power.—South river is highly esteemed as a water-power stream, having the reputation of great steadiness during the dry season. It is a good illustration of the difference between the type of streams represented by Table No. 54 and the flashy red sandstone water-sheds represented by Table No. 56, some of which may be found at no great distance from South river among the tributaries of the Millstone.

At Bloomfield mills, we estimate 6.4 horse-power per foot fall available during 9 months of the year. Ninety horse-power is ordinarily used on the 7 feet fall, the pondage here and above being sufficient to make this available during working hours. Manalapan creek, at Spottswood, having a water-shed of 42 square miles, will give 3.1 horse-power, and at Jamesburg, from 27 square miles, 2 horse-power per foot fall. There are a number of mill-powers in use on the upper branches, but usually rather small.

LAWRENCE'S BROOK.

This is the next tributary, rising near Monmouth Junction and flowing northeast 11 miles to the Raritan, just below New Brunswick. It drains 45 square miles, 17 per cent. of which is in forest, and the population is 59 to the square mile. The principal importance of this stream lies in the fact that it furnishes the water-supply of the city of New Brunswick, which is pumped from Weston's mills, about one mile above the mouth. The water-shed lies partly on the red sandstone and partly upon the clay district, and is largely overlaid with drift gravels, giving a ground-storage like that upon which Table No. 54 is based, consequently this table is to be used in computing its flow. The city of New Brunswick, in 1893, used an average of 1,521,097 gallons daily, from 35 to 86 per cent. of the amount used in each month being pumped by water-power. This water is satisfactory in quality and is used without treatment. We estimate that at the lowest monthly flow the stream will furnish 5,500,000 gallons daily. The facilities for storage are very fair. With storage equal to 2 inches on the water-shed, the available supply would be 15,600,000 gallons daily, and with 4.91 inches, 25,700,000 gallons daily could be obtained.

Water-power.—At Weston's mills, we estimate the power of this stream to be equal to 3.3 horse-power per foot fall available for 9 months, or 49.5 horse-power day and night upon 15 feet fall. At Milltown, on 34 square miles, 2.5 horse-power per foot fall is available. At this point a considerable amount of manufacturing is carried on.

MILLSTONE RIVER.

This is the next and one of the most important branches of the Raritan. It rises close to the source of South river, 26 miles south-southeast of its junction with the Raritan above Bound Brook. The stream is 35 miles in length, and between its easternmost and westernmost sources the distance is 30 miles. The fall along the main stream from the junction of Stony Brook to its mouth, a distance of 17 miles, is only 26 feet. The upper Millstone, above the junction of Stony brook, partakes of the general nature of the southern New Jersey sand-hill streams, and has large ground-storage. To this part of the stream Table No. 54 is applicable, while No. 56 should be applied to the red sandstone, and No. 55 to the main stream below the mouth of Stony brook.

Water-supply.—Like the Raritan, the lower Millstone is quite a muddy stream when swollen, and could not be used as a source of water-supply without settlement or filtration, although in other respects our analyses indicate a fair potable water. The population is 78 to the square mile, and 9 per cent. of the water-shed is in forest. We estimate the least monthly flow above Millstone village to amount to 29,600,000 gallons daily. The red sandstone branches are less desirable as a source of water-supply than the main stream. Some of the branches of the upper Millstone might afford water of very fair quality.

Water-power.—At Weston, from 283 square miles of drainage, we estimate 11.6 horse-power per foot fall available, and just below the junction of Stony brook, from 164 square miles, 6.7 horse-power per foot fall. We find along the main stream from 8 to 20 horse-power improved. Sixteen feet out of 26 feet total fall is in use. Royce's branch has a drainage of 18 square miles, and belongs to the type of streams whose flow is indicated in Table No. 56. It is not at all improved. Five-tenths horse-power per foot fall is available at its mouth. Six Mile run is another stream on the same type, draining 16 square miles. Forty-five hundredths horse-power per foot fall should be available at its mouth.

Beden's brook, draining 49.9 square miles, is another of the same class, which is also very little used. It is noticeable how little power is developed on streams of this type, compared with that improved on streams belonging to the class included in Table No. 54, or the Highland streams, of equal water-shed, a fact which our figures of flow fully explain. Stony brook is another stream of the same class. It has a water-shed of 64.8 square miles. Mill-owners report that in 1881 the stream was practically dry from 3 to 5 months, and no attempt was made to run the mills. This statement is corroborative of the results shown by Table No. 56. At the lowest mill, from 52 square miles drainage, 1.45 horse-power per foot fall is available, or about 3 horse-power for working hours.

On the upper Millstone, as we have remarked, Table No. 54 applies, and the whole stream, with 98.8 square miles drainage, we estimate will afford from its least monthly flow 12,200,000 gallons daily, or with 2 inches storage 34,400,000 gallons daily, being about 53 cubic feet per second. With storage amounting to 4.91 inches, which probably could be obtained with little difficulty, 56,500,000 gallons daily, or 87 cubic feet per second would be available. This stream with Stony brook, which with 7.25 inches storage would supply 57 cubic feet per second continuous, making for the two streams 144 cubic feet per second, might possibly be utilized for the supply of the proposed ship canal across the State. We have seen also that the upper Millstone might be suitable as a source of water-supply. It is not as desirable for this purpose as some of the Atlantic coast streams of southern New Jersey, and is not very likely to be utilized so long as such waters as those of the Highlands or Delaware river are available, and this remark applies equally well to the waters of the lower Raritan.

NORTH BRANCH OF THE RARITAN.

The main affluent of the North Branch, which is known as Lamington or Black river, rises less than a mile east of the foot of Lake Hopatcong, and 25 miles due north from its junction with the Raritan. The lower portion of the water-shed is on the red sandstone plain, having a general elevation of about 250 feet, but the principal and upper part is upon the Highlands, with an average elevation of about 750 feet, ranging as high as 1,100 feet. The whole drainage of the North Branch includes 191.6 square miles, 15 per cent. of which is in forest. The Highland portion has about 30 per cent. in forest. The population averages 72 to the square mile. To the

Highland tributaries Table No. 51 applies, and to the lower stream Table No. 55.

Water-supply.—The Highland portion of this stream is one of the desirable gathering-grounds of the State for a gravity supply. Lamington river above Pottersville drains 33 square miles. This area includes a marsh along the stream 7 miles long and one-fourth to three-fourths of a mile in width. The peaty matter from this marsh gives the water a brownish color, which gives rise to the name Black river, but the color is slight and would probably disappear after settlement. Above 500 feet elevation the drainage includes 31.4 square miles, which with 7 inches storage will supply 21,000,000 gallons daily. This storage may be obtained in the ravine above Pottersville and on Tanner's brook. When the iron mines at Chester and Hacklebarney are in operation there is a considerable amount of mine water poured into the stream, and this also would require settlement, but the mines are not likely to cause much trouble in the future.

The North Branch above the junction of Peapack brook drains 29.1 square miles above an elevation of 140 feet, which, with 7 inches storage, will supply 19,300,000 gallons daily. At the junction of Burnett brook, an elevation of 400 feet can be obtained with 17 square miles drainage, which will supply 11,300,000 gallons daily.

The north branch of Rockaway creek has a drainage area of 12.5 square miles above 400 feet elevation at Mountainville, from which, with 7 inches storage, 8,300,000 gallons daily may be obtained. This is in all respects an excellent gathering-ground.

Water-power.—At the mouth of the North Branch we estimate 7.8 horse-power per foot fall, and just below the junction of the Lamington river 6.35 horse-power. We find the average about 10 horse-power improved. There is a total of 30 feet fall, of which 10 feet is improved. Above Lamington river the North Branch has a high flood discharge. We estimate 3.2 horse-power per foot fall available, and below the mouth of Peapack brook 2.9 horse-power. Below Burnett's brook we estimate 1.2 horse-power. Between this and the mouth of Peapack brook there is a fall of 220 feet, 38 of which is improved. It is said that floods last about 36 hours from the beginning of the rise to their subsidence within the banks, and that the stream becomes quite muddy when swollen. At Roxiticus there is a water-power in use which is said to have been originally improved in 1680.

Peapack brook has 13 square miles of water-shed which is not very desirable as a source of water-supply. We estimate the power at the mouth, from this brook alone, at 0.9 horse-power per foot fall, but the mill there draws part of its power from the North Branch.

Lamington river drains 92 square miles, and we estimate 4.6 horse-power available at Burnt Mills for each foot fall. This stream rises quickly, and is said to become very muddy when swollen. At Pottersville, it is quite free from mud, and the total duration of floods is said to be about 36 hours. At this point, we estimate 2.2 horse-power per foot fall, and at Milltown, near Chester furnace, from 23 square miles, 1.5 horse-power. The fall between these two points is 420 feet, of which 105 is improved. Three hundred feet remains available, with an average of 1.8 horse-power per foot fall available during 9 months of the year.

Rockaway creek drains 39.4 square miles, or, at the junction of the North and South Branches, 36 square miles, giving 1.8 horse-power per foot fall available, and we find 3.3 horse-power improved.

SOUTH BRANCH OF THE RARITAN.

This stream rises in Budd's lake, the only natural lake upon the Raritan water-shed. Another of its branches, Drake's brook, rises at the foot of Lake Hopatcong close to the source of the North Branch. It is 42 miles long, encircling the water-shed of the North Branch on the northwest and southwest. It drains 276.5 square miles, of which about 100 square miles is in the Highlands, with an average elevation of about 750 feet, ranging as high as 1,200. The remainder is on the higher portion of the red sandstone, between 100 and 800 feet in elevation, with an average of about 400 feet.

Water-supply.—A small amount of water is pumped from the South Branch to supply Flemington, the pump being located at Kershaw & Chamberlain's mill. Above High Bridge, Table No. 51 applies, this being purely a Highland water-shed, with a drainage area of 67 square miles. The elevation here is 260 feet, and with 7 inches storage the stream will supply 44,700,000 gallons daily. Above Califon, at an elevation of 500 feet, the stream drains 55.5 square miles, and will supply, with the above storage, 37,000,000 gallons daily. The necessary reservoir capacity may be obtained on the main stream just above Califon, at Flanders, and just below the mouth of Turkey brook. The latter reservoir would have 11.3 square miles drainage, and would supply 7,400,000 gallons daily at an elevation of 800 feet.

Budd's lake is a beautiful sheet of water, nearly one and one-half miles long by three quarters of a mile wide. It has a water-shed of 4.5 square miles and will supply 3,000,000 gallons daily. Its elevation is 933 feet.

Spruce run has an area of 12 square miles above Glen Gardner at 440 feet elevation, and will supply 8,000,000 gallons daily with 7 inches storage. The other branches of the South Branch have little importance.

These Highland headwaters of the Raritan will furnish an aggregate gravity supply of 90,000,000 gallons daily above 400 feet elevation. They are second to the Passaic headwaters in desirability and about on a par with the Musconetcong.

Water-power.—At the mouth, we estimate 13.8 horse-power per foot fall. Above the mouth of Neshanic river, from 186 square miles drainage, 9.3 horse-power per foot fall is available, and at Hamden 145 square miles of drainage area will give 8 horse-power. Between these latter points we find from 15.5 to 20 horse-power improved. There is a total fall of 80 feet, of which 45 is in use. Above Clinton, with 112 square miles of drainage, we estimate 7.5 horse-power available, and at High Bridge, 4.6 horse-power. At Califon, we estimate 3.8 horse-power available for each foot of fall. Between this and High Bridge there is 220 feet fall, of which 74 feet is in use, leaving 146 feet with an average of 4.2 horse-power per foot fall, day and night, for 9 months of the year, still to be developed.

We estimate the power of Spruce run, at Glen Gardner, 0.83 horse-power per foot fall. At the lowest mill on Neshanic river, Table No. 56 gives 1.54 horse-power. This latter stream and all of the red sandstone branches upon the Raritan water-shed belong to the class of streams the flow of which is given in Table No. 56.

DELAWARE AND RARITAN CANAL.

This is the most important artificial waterway of the State. The main canal runs from the head of navigation on the Raritan, at New Brunswick, to the Delaware at Bordentown, a distance of 43 miles.

DAM ON THE RARITAN NEAR BOUND BROOK.

The feeder, which is also navigable, runs from the main canal, at Trenton, to the Delaware river, at Bull's island, a distance of 22 miles. A peculiarity of the canal is that its summit level extends almost to the banks of the Delaware, at Trenton, and the water of the Delaware river is brought through the feeder entirely across the State, emptying into the Raritan at New Brunswick. The width of the canal at surface is about 80 feet, at bottom 50 feet and it is 9 feet deep. There are 14 locks on the main canal and 2 on the feeder, making 16 in all. The locks are 220 feet long by 24 feet wide, with 7.5 feet of water over the mitre sills. The canal was built about 1833. Its cost was reported in 1854 to be $3,707,916, and in 1880, $4,735,353. The gross receipts in 1854 were $474,740, and in 1880, $419,431. The tonnage in 1880 was 1,348,082 tons. The maximum traffic upon the canal was probably during the civil war, when it was extremely heavy, taxing the canal to its utmost capacity. The season of navigation usually lasts from April 1st to the middle of December, or about 250 days. The traffic is drawn from ports on the Delaware river below Trenton, and those on Chesapeake bay through the Delaware and Chesapeake canal, and also from the Schuylkill canal and the Lehigh canal via the Delaware division of the Pennsylvania canal, boats being locked from the latter into the Delaware river and thence into the feeder at Lambertville. At the eastern end, the Hudson river ports and the Erie canal and ports on Long Island sound are reached, but at present the largest part of the traffic consists of coal from the Pennsylvania canals, carried to New York harbor, &c. Two classes of barges were in common use until recent years. Those from the small canals in Pennsylvania measure 90 feet long by 10.5 feet beam, drawing, when loaded, 5.5 feet of water, and the river boats from the Hudson river and the Erie canal, measuring about 100 feet long by 17.5 feet beam and drawing 7 feet of water when loaded. The canal will accommodate 500-ton barges, and recently barges of 300 tons and upwards have been considerably used. There is quite a considerable amount of freight carried in steam vessels. The water to supply the canal, excepting the 5.34 miles at the New Brunswick end, is drawn entirely from the Delaware river, at Bull's island. The feeder is also used as a raceway for water-power for the mills at Lambertville, a list of which is given in our Appendix I. We have observed from 516 to 260 cubic feet per second flow through the upper part of the feeder, the larger amount being that ordinarily used when all the mills are running. Of this, 192 cubic feet per second was used for the mills and returned to the river at Lambertville, 324 cubic feet per second being permanently diverted to supply the canal. Fifty-nine and two-tenths miles of canal and feeder have to be supplied with water for evaporation, leakage and lockage at Bordentown and Five Mile lock. At the time of our examination, about 100 cubic feet per second appeared to be used for this lockage, and the remainder, or about 3.7 cubic feet per second per mile, went to make good leakage and evaporation. The Raritan is drawn upon to feed the level from Five Mile lock to New Brunswick, and also to furnish power to the mills at New Brunswick. We have observed an average flow through this level of 254 cubic feet per second during the daytime, and the draught from the Raritan alone averages about 180 cubic feet per second day and night, only falling below this at the very rare intervals when the river flow becomes less. The above draught from the Delaware and Raritan must be taken into account in dealing with those streams below the points of diversion.

The following table gives the distance from the outlet lock at New Brunswick, and the elevation of the water surface of the canal above mean tide:

DISTANCES AND ELEVATIONS ABOVE MEAN TIDE, DELAWARE AND RARITAN CANAL.

	Distance. Miles.	Upper Level. Elevation in Feet.
Outlet Lock, New Brunswick	....	5
Deep Lock, New Brunswick	.67	17
Five Mile Lock, near Bound Brook	4.34	25.1
Lock, Bound Brook	7.01	32.5
Ten Mile Lock, Weston	9.51	40.9
Lock, Griggstown	19.01	48.8
Lock, Kingston	23.34	56.3
State Street Lock, Trenton	37.01	56.3
Prison Lock, Trenton	37.81	50.9
Lock No. 4, Trenton	38.67	42.4
Lock No. 3, Trenton	38.96	30.7
Lock No. 2, Trenton	39.56	18.4
Outlet Lock, Bordentown	42.89	8.7
High Tide, Bordentown	....	3.8
FEEDER.		
Canal at Trenton	....	56.3
Lambertville, below Lock	14.5	58.7
Lambertville, above Lock	......	68.7
Bull's Island, Delaware River	21.6	69.9

DELAWARE RIVER.

This stream rises in the State of New York, in the western Catskill region near the east line of Delaware county, the remotest source being near Hobart, at an elevation of about 1,900 feet. Its drainage in the State of New York is nearly co-extensive with Delaware and Sullivan counties. It forms the line between New York and Pennsylvania for nearly 100 miles above Port Jervis. At the northeasternmost corner of New Jersey, at the junction of Neversink creek, the total drainage area, including the Neversink, is about 3,600 square miles. The elevation of the river at this point is 411 feet. Thence to the Delaware capes, a distance of 245 miles, it forms the boundary of the State of New Jersey. The total length of the river to the capes is 410 miles, and above the head of the bay 360 miles. It is navigable with a low-water depth of 5 feet to Trenton, 130 miles from the capes, having a depth of not less than 22 feet at half tide up to Camden, 100 miles. Its drainage area above the head of tide and navigation at Trenton is 6,916 square miles, and below the mouth of, and including the Schuylkill, 10,100 square miles. Above the head of the bay the portion of its drainage area within the State of New Jersey amounts to 2,345 square miles, or about one-fifth of the whole, and the tributaries of the bay drain 1,060 square miles, making 3,405 square miles in all, or 45 per cent. of the whole State lying within the Delaware basin.

It will be seen from the above figures that this is the most important stream of the State, and that the interest of New Jersey in the stream, including all from Port Jervis to the bay, is a large one. The head of the bay we consider to be at Reedy island, 51 miles from the capes. Of the New Jersey branches of the Delaware, Flat brook, Paulinskill, Pequest, Lopatcong, Pohatcong, and Musconetcong rivers belong to our Kittatinny valley and Highland class of streams, the flow of which is given in Tables Nos. 51 and 52. These streams we have already considered. The branches below the mouth of the Musconetcong to Trenton are small, and all belong to the class of flashy red sandstone streams, the flow of which is given in Table No. 56. These we will consider later. The branches of the Delaware from Trenton to Camden, and those below Camden each form a class by themselves, and will be taken up hereafter. The more important branches outside the State of New Jersey are given in the accompanying table, the areas being mostly taken from Prof. George F. Swain's report on the Middle Atlantic water-shed, contained in Volume XVI. of the Tenth Census of the United States, to which report I am indebted for many facts relating to the Delaware watershed.

Branch.	Entering Delaware River at	Drainage Area. Square Miles.
Christiana Creek	Wilmington, Del	465
Schuylkill River	Philadelphia, Pa	1,912
Neshaminy Creek	Opposite Beverly, N. J	228
Tohickon Creek	Point Pleasant, Pa	102
Lehigh River	Easton, Pa	1,332
Bushkill Creek	Easton, Pa	75
Analomink, or Broadhead's Creek	Water Gap, Pa	289
Bushkill Creek	Bushkill, Pa	158
Neversink River	Carpenter's Point, N. Y	346
Lackawaxen River	Lackawaxen, Pa	597
West Branch	Walton, N. Y	348
East Branch	Above Beaver Brook, N. Y.	520

We have not a great amount of data as to the flow of these branches. The following table of dry-season flow for the Schuylkill is compiled from Prof. Swain's report in the Tenth Census already alluded to, and may be of interest in this connection:

DRY-SEASON FLOW OF THE SCHUYLKILL.

Drainage area, 1,912 square miles.

1816	771 cubic feet per second.
1825	680 " "
1867	617 " "
1874	380 " "
1876	310 " "

The last is at the rate of 0.165 cubic feet per second per square mile.

For the Neshaminy and Tohickon we have the tables of gaugings already given among our long series, on which we have based our conclusions as to evaporation and flow. The maximum and minimum flow of each is also given in Table No. 42. These streams are the types on which we have based Table No. 56, showing the flow of small red sandstone water-sheds with little ground-storage, and the type curve of ground-flow shown in Plate VI. is obtained from the above record also. The Lehigh is a very flashy stream with heavy flood-flow, the maximum being estimated from high-water marks to be about 55 cubic feet per second per square mile.

The percentage of forest upon the Delaware water-shed is not accurately known, but we can form an approximate idea from the areas of improved land in farms given in the Tenth Census. The difference between the total area of a county and the area of improved land in farms is found to be, in the New Jersey portion of the Delaware water-shed, 10 per cent. in excess of the amount of forest obtained from actual survey. Applying these figures we obtain the following table, which we believe is not far from the truth. We have set down the percentage of improved land, and of the remainder 10 per cent. has been classed as barrens. This portion includes waste land, highways, city and town sites, &c. The part classed as forest may be safely assumed to run pretty evenly through all the grades, from brush land to heavy timber:

POPULATION AND PROBABLE FOREST ON DELAWARE WATER-SHED.

	Population per Square Mile.	Improved Lands. Per cent.	Barrens. Per cent.	Forest. Per cent.
Above Water Gap..........	31	34	7	59
Above Easton................	43	39	6	55
Above Trenton...............	98	43	6	51
Lehigh River................	415	48	5	47

The above table shows also the population per square mile, which is seen to be very small for the portion above Easton. On the water-shed above the Water Gap the population has decreased considerably between 1880 and 1890, the above figures being based on the census of 1890. On the Lehigh and the lower water-shed the population is larger and increasing.

During a discussion of the flow of streams at a meeting of the American Society of Engineers, of which he was then Vice President, the late Ashbel Welch, C.E., gave the following information. This was November 3d, 1879:

"The river Delaware discharges, at the driest seasons, a little less than 2,000 cubic feet per second. * * * When I first knew the Delaware, nearly half a century ago, the minimum flow was probably 4,000 feet per second, twice as much as now.

"The 2,000 cubic feet per second was a measurement some years ago; the 4,000 cubic feet was a very rough measurement at the time in various ways, none of them accurate, but still corroborating each other, so that I probably got results within 10 per cent. of the truth.

"The discharge in the highest flood ever known before 1841, that of 1787, was not more than two-thirds as much as that in the great flood of 1841."

J. J. R. Croes—"Has there been any great flood since 1841?"

Ashbel Welch—"There have been two, one of which was nearly if not quite as high. The flood of 1841 and two subsequent floods must have discharged nearly twice as much water as any previous floods since 1787, and 50 per cent. more than the flood of 1787. I suppose that there is not, at the lowest stages, more than half the water in the Delaware that there was half a century ago, and that the highest floods carry off 50 per cent. more per hour than any flood known before 1841." (Trans. Am. Soc. C. E., July, 1881, page 243.)

In the Annual Report of the Chief Engineer, United States Army, for 1873, Appendix U 19, there is a full report on the Delaware between Easton and Trenton, made by Assistant Engineer Mansfield Merriman. The following notes of floods, known locally as "freshes," have been abstracted:

"The time required to bring a raft from these points to Easton varies with the height of water and direction and force of wind. In ordinary rafting freshets of five to ten feet (*rise*), however, the time appears to be, from Delhi to Easton, 165 miles, 40 to 48 hours; from Walcott to Easton, 165 miles, 40 to 48 hours; from Hancock to Easton, 125 miles, 30 to 36 hours; from Callicoon to Easton, 100 miles, 24 to 30 hours; from Easton to Trenton the time is from 10 to 12 hours; so that the entire trip from Walcott or Delhi to tide-water is performed in from 50 to 60 hours, showing the mean velocity to be from 4.3 to 3.6 miles per hour.

"In general it may be said that the river is subject to three classes of floods; the ice floods, which happen at the breaking up of the river; the rafting floods, occurring later, from the spring rains, and the fall floods, caused by the storms of September and October, which, however, are very irregular.

"The ice floods, at Easton, are usually from 10 to 20 feet in height, but on many occasions have been known to rise much higher, the 'great flood' of 1841 having reached 35 feet. The great accumulation of water here is owing to the influx of the Lehigh, a very turbulent stream in time of freshets, and to the narrow, steep banks between which the Delaware is confined, its width being less than 600 feet.

"The rafting freshets in the spring are of less rise, but of longer duration than the ice floods; at Easton, ranging from 3 to 10 feet; at Lambertville, 1 to 8 feet, and at Trenton, 1 to 6 feet. A very remarkable rise, however, occurred on June 8th, 1862, which was 32 feet at Easton, and next to that of 1841, the greatest flood on record.

"The following is a partial list of the 'great floods,' with the heights to which they rose, as nearly as can now be ascertained:

NAME OF FLOOD.	DATE OF OCCURRENCE.	HEIGHT TO WHICH IT ROSE ABOVE LOW WATER.
Pumpkin fresh	October 6th, 1786	16 feet at Lambertville.
	——— ——, 1798	Not as high as last, but exact height not known.
Jefferson fresh	——— ——, 1801	14 feet at Lambertville.
	——— ——, 1814	14 feet at Lambertville.
	March ——, 1832	12 feet at Lambertville.
	April ——, 1836	14 feet 6 inches at Lambertville.
	April ——, 1839	14 feet 6 inches at Lambertville.
Great flood	January 8th, 1841	35 feet at Easton, 23 feet at Bull's island, 20 feet at Lambertville, 28 feet at Lamsin's island.
	October 13th, 1843	14 feet at Lambertville.
	March 15th, 1846	17 feet 6 inches at Lambertville.
June fresh	June 8th, 1862	42 feet at Easton.
October fresh	October ——, 1869	Exact height not known.

"The point which has been particularly forced upon my attention, in connection with this subject, is the great frequency with which floods now occur, as compared with the time previous to 1835. While the preceding table is supposed to contain the record of every 'great freshet' previous to 1841, it by no means shows those occurring since that date. In fact, they have become too common to be a matter of record. Previous to 1835, floods of 12 feet, at Lambertville, were considered very high, while 14 feet had been attained only three times within the memory of man—in 1786, 1801 and 1814. But since that time floods of 14 feet have become common, while three have occurred—1841, 1846, 1862—in which probably one-third to one-half more water has been discharged than in any previously known. This is undoubtedly to be attributed to the clearing away of the forests in the river basin.

"To recapitulate, then, this branch of my subject, I may say that the stage of the river throughout the year is ordinarily as follows: January, frozen and medium height; February and March, breaking up and high; April, May and June, high; July, subsiding; August and September, low; October, low, but subject to high freshets; November, low, often very low; December, rising a little and freezing."

These stages agree well with those of the Connecticut, and the further agreement in low seasons and flood-discharges leads us to be guided by the valuable record of flow of this stream in computing the flow of the Delaware. The flood of 1869 rose 32 feet at Shapnack island, below Dingman's Ferry. At Walker's Ferry it was 2 feet lower than in 1841; it began to rise at midnight of Sunday, reached its height Monday at 3 P. M., and was within its banks again Tuesday afternoon. There was a high freshet on April 1st, 1854, on the upper Delaware. December 15th, 1878, there was a freshet which was nearly as high as that of 1869 at Smith's Ferry, according to Mr. D. H. Smith. This freshet rose 20 feet at Carpenter's Point. Mr. Smith says an ordinary freshet requires a day to reach its height, stays at its maximum only an hour or two, and recedes in another day.

The collection of fuller flood-notes of this stream is desirable, and a careful study of its flow should be made. Almost everywhere the flood plain of the river has been built up to the height of maximum floods, for with its rapid current the stream tears away great volumes of earth, and as soon as the water spreads over the flats, and the current is checked, this detritus is deposited.

At Centre Bridge a mark was made by Col. Simpson Torbett and Martin Coryell for the very low water of 1831, and since then, in 1879 and 1881, very low stages have been referred to the same mark. The mark is on the New Jersey abutment of the bridge. In 1831 the water was 12 feet below this mark; in 1879 12.5 feet, and in 1881 13.21 feet. (See Climatology, page 375.)

During the preparation of this report a series of gaugings has been made at Centre Bridge, at different stages of the river, for determining its discharge for given heights. From the results of these gaugings and observed slopes of the river at various stages, and recorded high-water marks of various floods, we have been able, by the use of the Kutter formula, to prepare the accompanying table of discharges, showing maximum and minimum flows at various dates:

COMPUTED FLOW OF THE DELAWARE AT CENTRE BRIDGE.

Drainage area, 6,790 square miles.

Dry-Season Flows.

DATE.	Height above low-water of 1831.	Mean velocity. Feet per second.	Area of cross section. Square feet.	CUBIC FEET PER SECOND.		
				Stream discharge.	Canal flow.	Total discharge.
Autumn, 1831*..............	0.	1.20	1,599	1,919	0	1,919
November, 1879*	—.50	1.05	1,230	1,291	575	1,866
September, 1881*............	—1.21	.82	850	697	575	1,272
November 3d, 1892.........	.24	....	....	2,350	440	2,790
September, 1894.............	—.31	1.05	1,344	1,411	310	1,721

Freshets.

January 8th, 1841*.........	25.2	11.68	21,716	253,643	1,000†	254,643
June 8th, 1862*..............	23.2	11.19	19,934	223,064	575	223,639
Assumed Rise	20.6	9.81	17,645	173,097	575	173,672
January, 1891................	15.	8.33	12,857	107,142	200	109,142
November 5th, 1890........	9.74	5.89	8,425	49,623	575	50,198
January 14th, 1892.........	9.24	....	....	48,500	200	48,700
August 24th, 1891...........	8.53	5.80	7,847	45,513	575	46,088
January 18th, 1892.........	7.82	....	....	36,400	200	36,600
April 7th, 1892...............	7.74	....	....	35,800	440	36,240
May 24th, 1892..............	7.49	....	....	33,900	440	34,340

*All gaugings before 1890 only approximate.

† The feeder had broken its banks; this is approximate.

Inasmuch as the highest velocities above shown exceed those usually given as sufficient to cause gradual destruction of a river-bed of stratified rock, we wish to call attention to one assumption in making up this table which may not be accurate. This is, that the height of the river-bed has remained unchanged since 1831. There is a fair probability that it has been lowered somewhat, and if so, the effect would be to make the discharge above given for 1831 somewhat greater than it should be. It must not, therefore, be too confidently assumed that the flow in 1881 was less than that in 1831, but even if such should be the case, it would be accounted for fully by the fact that the drought of 1831, as shown by the rainfall records of Philadelphia, in Table No. 11, was by no means so severe as that of 1881, consequently we have no warrant for the assumption that the minimum flow of the river is decreasing.

Still worse is it to draw inferences from the height of the river alone, because it neglects the fact that in 1831 no water was being diverted from the river into the canals, as was the case in 1879 and 1881. The canal flow given in the table includes that of the Delaware and Raritan canal feeder on the New Jersey bank, and that of the Delaware division of the Pennsylvania canal opposite.

The flood-flows in the table include two of the great floods of Prof. Merriman's list previously quoted, consequently we have the means of judging of the approximate discharges of the other floods in the list. That of 1786 may be estimated at 175,000 cubic feet per second. Those of 1801, 1814, 1836, 1839 and 1843 from 140,000 to 150,000 cubic feet per second, and that of 1832 at 115,000 cubic feet per second. It should be noted that in dealing with the floods on the Passaic and Raritan we consider nothing less than 8,000 cubic feet per second, or about 9 cubic feet per second per square mile. The equivalent for the Delaware at Centre Bridge would be 55,000 cubic feet per second. Our table above gives every rise from August 24th, 1891, to December 30th, 1892, including those as low as 34,000 cubic feet per second. The accompanying diagram of flow for this period gives a better idea of the fluctuations of the stream, especially if we compare it with the Passaic diagram for the same time. The fluctuations are quite sharp and frequent. It is to be noted that Mr. Welch remarks that there have been two floods since 1841 nearly as high. This probably refers to the floods of 1862 and 1869. Our table shows that of 1862 to have been two feet lower at Centre Bridge. It may be inferred, therefore, that the flood of 1869 is the one to which Mr. Welch referred as having been nearly or quite as high as that of 1841. Mr. Welch has remarked that the flood of 1841 must have discharged 50 per cent. more than the flood of 1787, by which we assume that he meant the flood of 1786, recorded by Prof. Merriman, and is seen to be in accordance with our figures, as we estimate 175,000 cubic feet for the former and about 255,000 cubic feet for the latter flood. He also says that the flood of 1841 probably discharged nearly twice as much water as any previous floods since 1787, and as we find nothing recorded in this interval exceeding 150,000 cubic feet per second, it will be noted that our figures for 1841 are really about 67 per cent. in excess of those reported in the interval. Our rainfall curves in Plate I. seem to suggest an explanation of this fact, as the Philadelphia record indicates that prior to 1841 there had been quite a long period of low rainfall, but in that year a maximum was reached. We also find that the next maximum, slightly greater than that of 1841, occurred about 1868 or 1869. Consequently we find nothing in the history of the great floods of the Delaware indicating that there has been any increase that is not explained by heavier rainfall.

The conditions which bring about extreme floods are usually either a heavy fall of warm rain upon the water-shed when it has already a heavy covering of snow, or else when the ground is so frozen that it cannot absorb any water; or, secondly, in summer the fall of rain to the extent of six or seven inches in excess of what the ground has the capacity to absorb. When such conditions occur a heavy flood must result, and it cannot be prevented by the presence of forests or the uncultivated condition of the water-shed. So with the extreme dry-season flow of a stream. It is determined by the rate at which the earth will deliver up its water at a time when this water is drawn far below the level at which it can be influenced by forests or crops. These figures for the Delaware seem to indicate, therefore, that we are not to look to any change in the extreme high floods or in the extreme low-season discharge, but the testimony given by Mr. Welch, and much similar testimony, nevertheless undoubtedly has a foundation, and these we believe to rest in a change, not in the extreme, but in the intermediate stages, as we shall explain more fully later. We may note, in this connection, that the earliest flood upon the Delaware of which we have record occurred in 1692. The language in which it is recorded, in Smith's History of New Jersey, Chapter XII., is suggestive, and may be profitably quoted. The "falls of Delaware" are at Trenton:

> "The first settlers of the Yorkshire tenth in West Jersey had several of them built upon the lowlands, nigh the falls of Delaware, where they had now lived, and been improving near sixteen years; they had been told by the Indians their buildings were liable to be damaged by freshets, and the situation of the place must have made it probable. They had, however, got up several wooden tenements and outhouses which, in the spring, were accordingly generally demolished. The snows suddenly melting above caused an uncommon overflow of the river; there have been many great floods since, but none quite so high;* it came upon them so unexpectedly that many were in their houses surrounded with water, and conveyed to the opposite shore by neighbors from thence in canoes. The water con-

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* This was written in 1765.

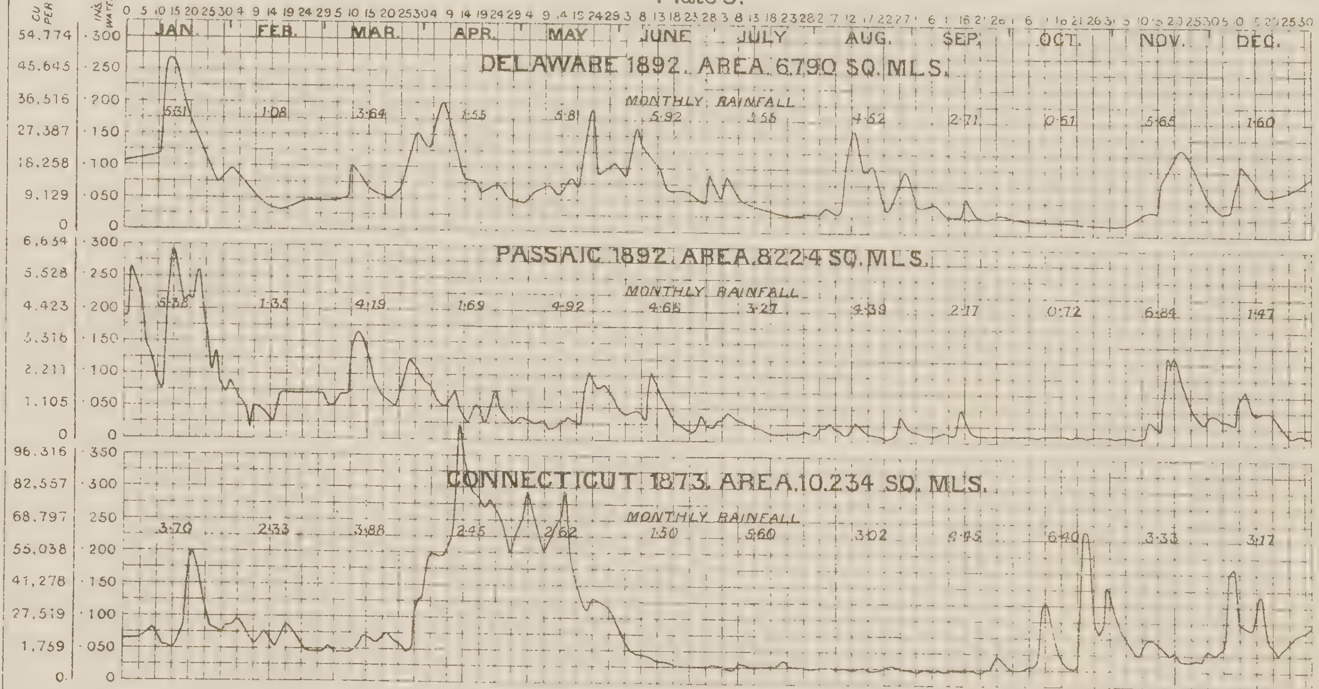
tinued rising till it reached the upper stories of some of the houses, then most or all of them gave way and were dashed to pieces; many cattle were drowned; beds, kettles and other furniture were picked up on the shores below; the frights and damages were considerable; two persons, in a house carried away by the sweeping torrent, lost their lives before they could be got out. This accident taught the owners here to fix their habitations on higher ground, and was what is commonly called *the great flood at Delaware falls*."

We have adopted the maximum and minimum flows shown in our table above for the Delaware. The former is at the rate of 37.5 cubic feet per second per square mile and the latter 0.19 cubic feet per second per square mile. The flood-flow from a large water-shed like that of the Delaware, having its branches distributed at intervals along the main stream, is invariably at a lower rate per square mile than for smaller water-sheds. We may illustrate the reason for this by a single example. The drainage areas of the Delaware above Callicoon and of the Lehigh river at Easton are about equal, and it appears that floods reach their maximum at these two places in about the same time from the beginning of the rise. The distance from Callicoon to Easton, however, is 100 miles, and we have seen that it takes a raft, during a rise of from 5 to 10 feet, from 24 to 30 hours to traverse this distance, floating with the current. It will be seen that this gives sufficient time for the Lehigh flood to be entirely discharged before that from Callicoon reaches Easton, consequently the two floods pass down the lower river in succession, and the duration of a flood on that part of the stream is longer but the rate of discharge is less.

The accompanying table of gaugings at Stockton, or Centre Bridge, covering over 16 months, indicates that the evaporation from the Delaware water-shed is about 17.7 per cent. less than what we have observed for the Passaic, Croton and Sudbury, whereas the difference in mean temperature would account for a difference of 11.5 per cent. only. In the absence of a longer period of gaugings, we prefer to adopt the evaporation deduced from temperature, as this will give a flow which will be on the safe side. We have used the above gaugings in connection with the series previously given for the Connecticut river to determine the ground-flow curve for the Delaware, shown in Plate VI.

We have estimated the flow of the Delaware to be as shown in Table No. 57.

Plate 9.



COMPARATIVE FLOW OF DELAWARE, PASSAIC & CONNECTICUT.

J.R. Prince, Del.

FLOW OF DELAWARE RIVER AT STOCKTON, N. J.

Drainage area, 6,790 square miles.

MONTH.	Rain—Inches.	Flow—Inches.	FLOW IN CUBIC FEET PER SECOND.		
			Greatest.	Least.	Average.
1891.					
August 24th to 31st	....	....	45,513	12,290	....
September	1.98	1.11	13,075	3,395	6,776
October	3.12	.72	8,075	3,045	4,236
November	2.67	.92	23,575	3,045	5,569
December	4.59	2.54	24,600	8,700	14,800
1892.					
January	5.31	4.78	48,700	12,900	28,120
February	1.08	1.56	17,300	5,750	9,760
March	3.64	2.35	27,500	8,800	13,773
April	1.55	3.02	36,240	9,640	18,421
May	5.81	2.65	34,340	7,990	15,573
June	5.92	2.63	28,640	7,990	16,040
July	3.55	1.36	15,640	4,740	8,027
August	4.52	2.21	28,640	5,040	12,971
September	2.71	.97	9,640	3,940	5,880
October	.61	.53	3,600	2,490	3,104
November	5.65	1.67	23,940	2,790	10,923
December	1.60	2.14	19,990	6,640	12,591

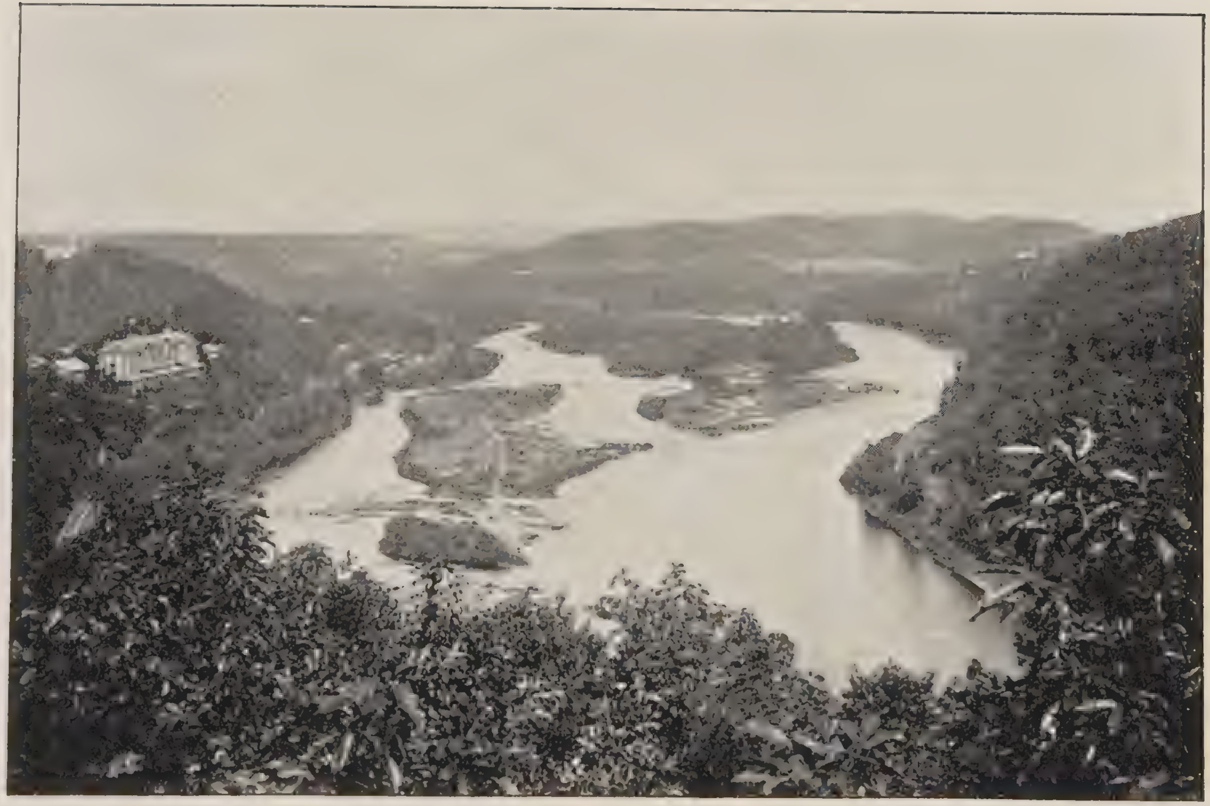
	Rain—Inches.	Flow—Inches.
December to May, 1891	21.98	16.90
June to November, 1891	22.96	9.37
	44.94	26.27

TABLE No. 57.

Estimated Flow of Delaware River above Trenton.

	December.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	Year.
AVERAGE YEAR.													
Inches of rainfall	3.67	3.57	3.40	3.67	3.57	3.99	3.99	4.17	4.52	3.67	3.40	3.67	45.29
Inches flowing off	2.97	3.01	2.83	2.92	2.48	1.74	1.26	.90	.87	1.10	1.92	2.75	24.75
Flow in thousand gallons daily per square mile.	1,660	1,680	1,695	1,640	1,440	975	730	505	487	670	1,070	1,590	1,180
Horse-power on one foot fall per square mile	.292	.297	.298	.288	.253	.181	.128	.089	.086	.112	.189	.280	.207
ORDINARY DRY YEAR.													
Inches of rainfall	3.95	4.04	1.67	2.95	2.60	3.36	3.73	4.47	3.93	.99	2.09	2.22	36.00
Inches flowing off	3.23	3.45	1.25	2.28	1.76	1.37	1.04	.87	.80	.60	.52	.69	17.86
Flow in thousand gallons daily per square mile.	1,810	1,930	750	1,280	1,015	768	603	487	448	347	291	400	850
Horse-power on one foot fall per square mile	.318	.340	.131	.225	.179	.135	.106	.086	.079	.061	.051	.070	.149
DRIEST PERIOD.													
Inches of rainfall	4.05	3.66	4.76	3.83	.61	2.71	3.87	.96	1.18	.94	3.04	2.02	31.63
Inches flowing off	3.32	3.09	4.09	3.07	1.03	.71	.69	.43	.26	.22	.23	.29	17.43
Flow in thousand gallons daily per square mile	1,860	1,730	2,450	1,720	595	398	400	241	145	127	129	168	828
Horse-power on one foot fall per square mile	.327	.305	.430	.303	.105	.070	.070	.042	.026	.022	.023	.030	.146
Continued.													
Inches of rainfall	2.63	4.57	4.22	3.57	2.12	5.06	1.90	1.37	6.40	1,209	1.32	.99	46.24
Inches flowing off	.40	1.94	3.58	2.83	1.54	2.13	.90	.59	.40	6.90	1.23	.80	23.24

To utilize 14 inches per annum upon this water-shed, or 666,094 gallons daily per square mile, we shall need 5.07 inches of storage, or 88,106,000 gallons per square mile. The reservoirs will be drawn down 13 consecutive months during the driest period, filling about the end of April. The horse-power available during 9 months of the ordinary dry year is .079 per square mile for each foot of fall. The least flow is at the rate of .02 horse-power per foot fall per square mile.



LOOKING UP THE DELAWARE RIVER FROM THE WATER GAP.

Water-supply.—The Delaware has great prospective value as a source of water-supply for the cities of our own and adjacent States. While below Easton and the confluence of the Lehigh there is growing contamination, it will be seen by the results of chemical analyses, which we furnish later, that there are at present no evidences of serious pollution above the city of Trenton. We have previously shown the proportion of forest and the population per square mile, both of which are good indications of its fitness as a source of supply, especially above Easton. The portion above the Water Gap is not likely to become more populous for a long period of years, and furnishes, in all respects, a most desirable gathering-ground for public water-supply. Although it may be in the far future, we believe that this is destined to become the ultimate recourse of our large metropolitan district. The Delaware already supplies 142,636 inhabitants of New Jersey with water, the total consumption being 17,010,464 gallons daily. At Trenton, the maximum flow we estimate at 1,314 cubic feet per second under natural conditions, but 383 cubic feet per second is diverted for canal purposes, leaving 931 cubic feet per second minimum flow. Probably the river does not fall as low as this oftener than once in a generation. This gives 601,600,000 gallons daily as the supply without storage. Water is pumped from the river here for the supply of the city of Trenton. At the least monthly flow shown by the table, the natural flow of the river at Trenton amounts to 880,000,000 gallons daily. At Point Pleasant, it has already been proposed to pump water from the river for the supply of the city of Philadelphia, the pumping to be done by water-power. The elevation of the river here is 69 feet, and the drainage 6,620 square miles. We estimate the minimum flow to be 1,258 cubic feet per second, or 810,000,000 gallons daily, and the least monthly flow, as per the table, 840,000,000 gallons daily. At Phillipsburg and Easton, above the mouth of the Lehigh, the water-shed is 4,880 square miles and the minimum flow 930 cubic feet per second, or 600,000,000 gallons daily. With storage amounting to 5.07 inches on the water-shed, the total supply would be 3,250,000,000 gallons daily.

At the Water Gap, at an elevation of 296 feet, we have 4,020 square miles drainage and a minimum flow of 764 cubic feet per second, or 494,000,000 gallons daily. With storage amounting to 5.07 inches on this water-shed, the total supply in the driest period will amount to 2,680,000,000 gallons daily. While we have no complete surveys of this area, from what we know of it, it is believed that this storage could be readily obtained. At the State line, the water-shed, including Neversink river, is 3,600 square miles, and we estimate a minimum flow of 673 cubic feet per second, or 435,000,000 gallons daily. At the least monthly flow shown in the table, 457,000,000 gallons daily is available, and with storage amounting to 5.07 inches, 2,400,000,000 gallons daily may be obtained.

Water-power.—In the past, the rafting, and earlier, the flat-boat navigation of the Delaware, and also the fishing interests, have had an importance considerably greater than the water-power, and, in consequence, legislation has favored the former at the expense of the latter. Under the changed conditions which now exist, it is probable that it would not be difficult to obtain a modification of the laws more in conformity with the present relative importance of these various interests, and more favorable to the development of water-power. Under the present conditions, it is difficult to build proper dams. While it may be possible to dispense with high dams, it is very necessary that they should be reasonably tight, so that the whole of the minimum flow may be made available. For the most part, conditions are favorable to development by means of low dams and long raceways, although cases exist where high dams would be preferable. There seems little doubt that a large amount of water-power on the Delaware could be profitably utilized. A great deal is being done in the West, where the natural difficulties are greater than upon this stream, and if it had not been that fuel was much cheaper here, there can be little doubt that the Delaware would have been much more fully utilized. Much of this power is favorably situated for electric transmission to Trenton and other manufacturing points, or for use as a motive power for electric railways.

The first developed water-power of any importance upon the river is that of the Trenton Water-Power Company, consisting of a low and leaky dam of stone and timber, containing a chute for the passage of rafts, and a raceway six and three-quarter miles in length. The dam is at Scudder's falls, at an elevation of 21 feet, and a list of the water-power is given in Appendix I. It is used on heights varying from 9 to 14 feet, and a total of 796 gross horse-power is rented. The rental is said to be approximately equivalent to $50 per gross horse-power per annum, but varies somewhat, the preference being given to some of the original lessees. This water-power company was originally incorporated as the Trenton Delaware Falls Company in 1831, and the works were considerably improved in 1866. We estimate that the power actually used is equal to 55 horse-power on 1 foot fall, or about 484 cubic feet per second. We estimate the least natural flow of the river to be 1,314 cubic feet per second, and deducting the above amount and 383 cubic feet per second diverted for the use of the canal, we still have 447 cubic feet per second unused at Trenton at the time of minimum flow, or 50.7 horse-power per foot fall, and the amount becomes as little as this probably not oftener than once in a generation. We estimate the total available power during 9 months of the year, exclusive of the amount used by the Trenton Water-Power Company and the canals, to be 447 horse-power per foot fall. Eight feet fall may be readily obtained by a low dam and short raceway, so that we have at the minimum 406 horse-power, and for 9 months of the year, 3,576 horse-power. The lowest flow in an ordinary dry year would give 256 horse-power per foot fall, or 2,048 horse-power on 8 feet fall day and night. The same amount of power per foot fall is available at any point from Trenton to below the dam at Scudder's falls, the total fall of the river in this distance being 21 feet. Five feet of this fall could be readily developed at Gould's rift, just below the Reading railroad bridge, giving 250 horse-power at the lowest stage of the river, 1,280 horse-power at the lowest for ordinary dry years and 2,200 horse-power for 9 months of the year, exclusive of the amounts used by the Trenton Water-Power Company and the canals. Just above Scudder's falls, it would be practicable to build a dam 15 feet in height and still to leave room for the passage of floods without interfering with the canal and railroad. Such a dam would back water to the foot of Welles falls, and would develop 1,575 horse-power at the minimum flow of the river, as we have here to allow only for the water diverted through the canals. Seven thousand five hundred horse-power would be available on this fall during 9 months of the year. At the head of Welles falls, at Lambertville, we estimate, after allowing for canal diversion, a minimum of 103 horse-power per foot fall, and for 9 months of the year, 494 horse-power. There is a fall of 14 feet here in a distance of 1,500 feet, which would give a minimum of 1,442 horse-power, and for 9 months of the year, 6,900 horse-power day and night.

Appendix I. shows the water-power in use along the feeder of the Delaware and Raritan canal. Above Lambertville 107 gross horse-power is used; at Lambertville 452 horse-power, and below 183 horse-power, all of which water is drawn from the feeder and flows into the river, while the water passing from the upper to the lower level of the feeder at Lambertville affords 636 horse-power, giving a total of 1,378 gross horse-power furnished by the feeder. We estimate the total minimum flow of the river at Bull's island, at the head of the feeder, to be 1,285 cubic feet per second, and allowing for 324 cubic feet needed to supply the canal below, 961 cubic feet per second, or 109 horse-power per foot fall, could be obtained at Lambertville if all of the water of the river should be diverted into the feeder. As 18 feet fall is obtainable there, 1,962 horse-power would be furnished. This power could be had by simply tightening the dam at Bull's island, and perhaps slightly raising the banks of the feeder, as this upper part of the feeder has practically no use for purposes of navigation. At Point Pleasant, just above Bull's island, Mr. Rudolph Hering, C.E., in his Report upon Surveys for Future Water-Supply for the City of Philadelphia, in 1885, estimated that at a cost of $684,669 a plant could be installed at Point Pleasant, with 15 feet fall, including a masonry dam, forebay, turbines, &c., complete. We estimate here for the minimum flow 146 horse-power per foot fall, which would give, on 15 feet fall, 2,190 horse-power. The least flow for ordinary dry years would give 7,095 horse-power, and the power available for nine months of the year would be 8,025 horse-power. This is evidently a fine opportunity to develop a large amount of power. Six per cent. on the above cost would make the cost of the minimum power only $19 per annum per gross horse-power for 24 hours daily, which is a low rate. We are now above the point where the river flow is affected by the draught of the Delaware and Raritan canal.

The above dam would back water to the rapids known as the Tumble, one and one-half miles above. Just above, near Tumble station, another 15-foot fall could be developed with the same power as that at Point Pleasant. It will be seen that we have, on a distance of two and one-half miles along the river, and at a point 25 miles from the city of Trenton, an aggregate minimum power of 4,380 horse-power day and night, and almost always a large amount of surplus power.

DELAWARE RIVER AT FOUL RIFT.

Below the mouth of the Lehigh, at Easton, we estimate a minimum of 134 horse-power per foot fall, and for 9 months of the year 490 horse-power per foot fall. The total fall of the river from this point to the head of the power above mentioned at Tumble is 56 feet. At several intermediate points, by a similar development, powers as good as this mentioned at Point Pleasant could be developed, or for less expensive development by low dams and raceways we have the following: Ferman's falls, below Milford, 6 feet fall by a low dam and raceway, 1,000 feet long; Nockamixon falls, at Holland station, 5 feet fall by a low dam and 1,300 feet of raceway; Lynn's falls, at Holland station, 9 or 10 feet fall with 2,000 feet raceway; at Durham falls, 4 feet; Rocky falls and Groundhog falls together, 6 feet; Old Sow and Clifford, 10 feet fall by a low dam and one and one-half miles raceway, and at Phillipsburg rift, 6 feet fall.

Above the mouth of the Lehigh, at Phillipsburg, we estimate the minimum power at 106 horse-power per foot fall, and for 9 months of the year 386 horse-power. Below the mouth of the Pequest, at Belvidere, we have a minimum of 102 horse-power, and for 9 months 370 horse-power per foot fall. Between this and Easton the total fall is 73 feet, and at several points from 10 to 15 feet fall could be readily developed. At Foul rift, just below Belvidere, a total fall of 16 feet could be obtained, either by a dam at the head of the rift and a raceway, or a higher dam near the foot of the rift. The bed of the river here is solid ledge. This would give a total of 1,632 horse-power minimum and 5,920 horse-power for 9 months of the year.

At the Water Gap we estimate the minimum at 87 horse-power, and for 9 months 317 horse-power per foot fall. The total fall to Belvidere is 60 feet, and two sites of 10 feet each could be obtained between Belvidere and Manunka Chunk. There are several opportunities to develop from 5 to 10 feet. Near Port Jervis, at the State line, we estimate a minimum of 78 horse-power, and for 9 months 284 horse-power per foot fall. The total fall from here to the Water Gap is 111 feet, with several opportunities to develop from 10 to 20 feet fall if desired, and there are no improvements to be interfered with.

RED SANDSTONE BRANCHES OF THE DELAWARE.

These streams belong to the flashy class, of which the flow is given in Table No. 56. This table is based on the flow of the Tohickon and Neshaminy, on the Pennsylvania side of the river, and very similar to these New Jersey branches. They have only a local importance, and are none of them of large size, their chief distinction being their unusually long Indian names.

Hakihokake creek enters the Delaware at Milford, and drains 17.4 square miles. Its water-shed lies partly upon Musconetcong mountain, one of the Highland ridges, consequently its flow is probably somewhere between that shown by Table 51 and Table 56. There is some power developed at Milford, and we estimate about 0 9 horse-power per foot fall at that point.

Harihokake creek drains 10.1 square miles, giving about 0.4 horse-power per foot fall at its mouth. Nichisakawick creek drains 10.5 square miles, and Lockatong creek is somewhat larger, draining 23.8 square miles. Its headwaters are on a high and level red sandstone plateau, and in the short distance between Milltown and the Delaware its total fall is 340 feet, so that even with its rather small flow in dry seasons a considerable amount of power could be developed. We estimate 0.66 horse-power per foot fall at the mouth, and 60 feet fall could be quite readily improved, giving 40 horse-power continuous for 9 months. Wickecheoke creek drains 26.9 square miles, with an available power of 0.75 horse-power per foot fall at the mouth. Alexsocken creek enters the Delaware just above Lambertville, but offers no very good opportunities for development. Swan's creek, at Lambertville, lies mostly upon the trap ridge east of this place, and supplies the city with water by gravity. Above the reservoirs the drainage area is about 1.5 square miles, and the present consumption of water is 200,000 gallons daily, there being 22,000,000 gallons storage.

Those who are familiar with these streams will not fail to appreciate the low summer flow which is ascribed to them by Table No. 56. They are very often dry during the autumn months, but, as shown by the table referred to, owing to the fact that there is much less storage to be depleted, and consequently, less to be made good in a time of replenishment, they feel the effects of heavy rains much more quickly than streams with larger storage. It is also true that the rate at which rain can be absorbed by these water-sheds, even when the storage is depleted, is limited, consequently, if rain falls heavily in a very short time, it sometimes runs off in floods without entirely replenishing the depleted storage.

SOUTHERN NEW JERSEY STREAMS.

The remaining streams of the State all have a strong family likeness, owing to a marked similarity in the topography and geology of their water-sheds. Practically all of these are below 200 feet elevation. They are flat and consist mainly of sand and gravel, consequently we need but two curves of ground-storage for the whole district. These are shown in Plate VI. The one for streams of low relief and smaller ground-storage is based partly upon the flow of the Rancocas, as shown in the tables of gaugings which we give later, and partly upon other data. The second type, based on the gaugings of Great Egg Harbor river, is suited to the larger streams, having a considerable amount of swampy area upon their water-sheds or a higher and bolder relief. It will be seen that the flow of these streams for a given depletion of ground-water is much larger than that of northern New Jersey streams. A part of the heavy run of the streams during the earlier months is undoubtedly from swamp-storage. The wooded swamps of southern New Jersey are full of fallen logs, peaty matter and absorbent mosses, which retain the water almost like a large lake. This water finds its way gradually out to the stream, and finally, in very dry times, the swamp becomes drained to a great depth, as evidenced by the depth to which fire penetrates when they become ignited at such seasons. At the beginning of the dry season this swamp-water is constantly replenished by the ground-water coming in from the higher areas of sand and gravel. It is no doubt the final depletion of this swamp-storage which is marked by the rapid fall of the flow curve when storage depletion has reached four or five inches, but the lowest flow which we have any record of for these streams does not fall below 0.3 inch per month. For all of this part of the State the temperature is about the same, so that evaporation is everywhere 14 per cent. in excess of that given by the Passaic formulæ. In our analysis of rainfall we have seen that the average varies sufficiently to divide the district into three subdivisions. These are designated as Branches of Delaware below Camden, Branches of Delaware, Camden to Trenton, and Coast streams. Maurice river has been included in the latter class, as, although it is in the basin of the Delaware, it partakes of all the climatic and topographic features of

Great Egg Harbor, Mullica and other coast streams. This last large subdivision is divided into two types of stream, one for each of the classes represented by the two storage curves which we have noted. The two subdivisions on the Delaware slope are both represented by the curve of smaller storage-flow, consequently each of these is represented by one flow table only. Tables Nos. 58, 59, 60 and 61, therefore, show the several types of flow of southern New Jersey streams. It is instructive to compare the above tables with those for northern New Jersey streams. The better-sustained dry-season flow is very apparent, but nevertheless the total run-off from these streams is seen to be less than for those of the north. The heavy draughts upon ground-storage, of course, have to be made good at the end of a dry period, and the result is shown in the relatively lighter run-off of the second year of our driest period, although the first year shows a larger total flow in the face of the much larger evaporation, as will be seen by comparing with Table No. 51 or 52. Another effect of this large yield of water from storage is the greater capacity for absorbing heavy rains, such as that of the second September of our driest period. It is noticeable that in southern New Jersey, during that September, our tables show a stream yield of 2.32 to 1.78 inches against from 7.27 to 6.90 inches for Kittatinny valley and Highland streams, or the Delaware. Of course the great evaporation has its effect here also, but the difference is mainly due to the large depletion of ground and swamp-storage. There is no lack of evidence of this much lighter flood-flow. We find it everywhere in the small preparations made for the overflow of dams, dependence often being had almost entirely upon flood-gates to carry away the surplus water, and the limited bridge opening, the long embankments of sand and gravel thrown boldly across the valleys in a manner that would mean disaster in a few months if attempted on our northern streams, and in many similar constructions which stand intact here for centuries. Such evidence is conclusive as to the small flood-flow.

The maximum discharge of these streams appears to rarely exceed 25 cubic feet per second per square mile. We have remarked that the total run-off of these streams is less than that of northern New Jersey, but this is made up in a measure by the fact that their more equable flow enables us to utilize a given amount with less storage. The streams which we have gauged are excellent types of all, and we have procured some data for other streams sufficient to prove that these gaugings fairly represent their flow. As we have remarked, these gaugings we have made the base of the storage curves in Plate VI.

TRIBUTARIES OF DELAWARE—TRENTON TO CAMDEN.

The flow of this group of streams is shown in Table No. 58, based upon gaugings of the Batsto and Rancocas. They lack the great swamp-storage peculiar to some of the coast streams, but nevertheless have a large yield from ground-storage.

ASSANPINK CREEK.

This stream rises near Clarksburg, Monmouth county, and flows almost due west 17 miles, joining the Delaware at Trenton. It drains 89.6 square miles, 27 of which is on the red sandstone, and the balance upon the clay and marl region, including a very level area in all respects similar to that drained by the upper Millstone.

The stream is not a desirable one for water-supply, owing to the agricultural character of its water-shed and its flatness. It is also rather muddy. We estimate the power at Whitehead's rubber-mill at 4.9 horse-power per foot fall for 9 months of the year. From here to the Delaware the total fall is 40 feet, most of which is utilized. At the mouth we estimate the available power at 6.75 horse-power per foot fall.

CROSSWICKS CREEK.

The headwaters of this stream are near Wrightstown, 10 miles southeast of where it empties into the Delaware, near Bordentown. It drains 139.2 square miles, almost entirely included in the marl region of the State. Its headwaters are on a very level plain, while the lower portion traverses a small valley 50 or 60 feet deep, and usually less than half a mile wide. The principal tributary is Doctor's creek, rising near the headwaters of the Assanpink, at Clarksburg, and flowing west 13 miles to its junction with the Crosswicks at Yardville.

TABLE No. 58.

Flow of Tributaries of the Delaware—Trenton to Camden.

AVERAGE YEAR.

	December.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	Year.
Inches of rainfall	3.82	3.73	3.55	3.82	3.73	4.16	4.16	4.35	4.71	3.82	3.55	3.82	47.22
Inches flowing off	*2.12	3.00	2.80	2.84	2.32	1.95	1.17	.88	.80	.81	.87	1.10	20.66
Flow in thousand gallons daily per square mile	1,185	1,680	1,675	1,590	1,340	1,090	677	492	448	469	487	637	985
Horse-power on one foot fall per square mile	.209	.296	.294	.280	.236	.192	.119	.087	.079	.082	.086	.112	.174

ORDINARY DRY YEAR.

	December.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	Year.
Inches of rainfall	4.13	4.21	1.75	3.08	2.73	3.62	3.90	4.64	4.09	1.03	2.18	2.34	37.60
Inches flowing off	3.19	3.42	1.21	2.18	2.07	1.41	1.00	.86	.76	.48	.40	.30	17.28
Flow in thousand gallons daily per square mile	1,785	1,915	725	1,220	1,200	790	579	482	425	277	224	173	822
Horse-power on one foot fall per square mile	.315	.337	.127	.215	.211	.139	.102	.085	.075	.049	.039	.031	.145

DRIEST PERIOD.

	December.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	Year.
Inches of rainfall	4.05	3.66	4.76	3.83	.61	2.71	3.87	.96	1.18	.94	3.04	2.02	31.63
Inches flowing off	3.10	2.93	3.87	2.85	1.46	.91	.84	.46	.30	.30	30	.30	17.62
Flow in thousand gallons daily per square mile	1,735	1,640	2,315	1,595	845	510	486	257	168	173	168	173	837
Horse-power on one foot fall per square mile	.306	.289	.406	.281	.149	.089	.086	.045	.030	.031	.030	.031	.148
Continued.													
Inches of rainfall	2.63	4.57	4.22	3.57	2.12	5.06	1.90	1.37	6.40	12.09	1 32	.99	46.24
Inches flowing off	.30	.47	.87	1.46	1.66	1.45	.96	.58	.40	2.32	1.63	.98	13.08

* The depletion of ground-water at the end of the average year being 0.79 inch, this amount is deducted from December flow in the table.

To utilize 12 inches per annum, or 570,938 gallons daily per square mile, 4.95 inches storage is needed. To have the reservoirs fill in the eighteenth month of the driest period, we should only attempt to utilize 10 inches per annum, or 476,090 gallons daily per square mile, which will require 3.28 inches storage, or 57,000,000 gallons per square mile. For 9 months of the ordinary dry year .075 horse-power per foot fall is available for each square mile of water-shed.

Water-supply.—The highly-agricultural character of this watershed is not favorable to its purity for water-supply purposes, nevertheless the chemical analyses which we give in a later chapter do not indicate any serious natural impurities. The water is used for the supply of Bordentown and has not given entire satisfaction, but this is believed to be due to unwholesome marshes on the lower portion of the stream and to local sewage contamination. We estimate the total supplying capacity of the stream, without storage, at 23,600,000 gallons daily at its mouth. At Groveville, above the junction of Doctor's creek, we estimate the total flow, without storage, at 18,400,000 gallons daily, or with storage to the amount of 57,000,000 gallons per square mile, 51,500,000 gallons daily. A considerable amount of storage could be procured along the main stream.

Doctor's creek will supply, without storage, 4,500,000 gallons daily at its mouth and 2,900,000,000 gallons daily at Allentown. It is probably, on the whole, less desirable than Crosswicks creek.

Back creek is a small tributary of the Crosswicks, near its mouth. It will supply at Lowry's mill-pond 1,340,000 gallons daily without storage. The result of a chemical analysis of this stream is also given in a later chapter.

Water-power.—Below the forks of Doctor's creek, we estimate the available power of Crosswicks creek at 9.3 horse-power per foot fall. The stream is navigable, however, up to Groveville for canal boats, and power cannot well be developed below this point. At Groveville, we estimate 8.1 horse-power per foot fall, which is just the amount utilized. At Crosswicks, we estimate the available power for 9 months of the year at 8 horse-power per foot fall. This is the amount practically in use here also. Just above this place, 20 feet fall could be improved without interfering with any improvements upon the stream. This would give 160 horse-power day and night for 9 months of the year, and in the driest month, 65 horse-power day and night. At Walnford, we estimate 6 horse-power per foot fall. Twenty feet fall could be had here also, giving 120 horse-power for 9 months of the year. The amount of power which has been developed on this stream ranges very close to our estimates of available power for 9 months, and indicates that the judgment of good millwrights has not been at fault.

On Doctor's creek, at Yardville, we estimate 2 horse-power per foot fall. The pondage is good, and at least twice this amount is no doubt available for working hours. At Allentown, we estimate 1.3 horse-power per foot fall, which is also probably double for working hours.

Black's creek.—This is a small stream, draining 22 square miles, and its water-shed contains a good deal of marl. The water has a green color and is not of use for water-supply. At the lowest mill site, we estimate 1.6 horse-power per foot fall, there being sufficient pondage to double this for working hours.

Assiscunk creek.—This stream is generally similar to Black's creek. Its Indian name signifies muddy or dirty creek, and it is not worthy to be considered as a source of water-supply. There is at present no power developed upon this stream, which is somewhat remarkable. At the first bridge above Burlington, the drainage being about 40 square miles, we estimate 3 horse-power per foot fall available for 9 months, and as much as 20 feet fall could be improved, giving 60 horse-power day and night.

RANCOCAS CREEK.

Excepting Maurice river, this is the largest tributary of the Delaware from the State of New Jersey. Its total drainage area is 301.4 square miles. The main creek is tidal on the North Branch to Mount Holly, and on the South Branch to Lumberton. It is navigable, with 4.5 feet depth at low water, to Centerton. The stream forks 7 miles from its mouth, and the South Branch, its principal affluent, drains 167 square miles. Its headwaters are upon the pine plains of the Tertiary formation, and consequently it partakes more of the character of the coast streams than the other streams of its class.

We have a short series of gaugings of the Rancocas at Pemberton. While these gaugings would be too short of themselves to afford a reliable indication of the flow of the Rancocas, they are long enough to show us the similarity of this flow to that of the Batsto, for which we have a much longer record.

FLOW OF NORTH BRANCH OF RANCOCAS AT PEMBERTON, 1890.

Drainage area, 111.7 square miles.

MONTH.	Rain—Inches.	Flow—Inches.	FLOW IN CUBIC FEET PER SECOND. Greatest.	Least.	Average.
March	5.48	3.21	590	161	300
April	2.18	1.93	329	118	192
May	3.20	1.53	189	132	148
June	3.76	1.84	244	129	183
July	5.38	1.37	211	82	132
August	4.49	1.25	144	97	120
Total	24.49	11.13	....	....	....

For this series we are indebted to Mr. Anthony J. Morris, of Pemberton.

COMPARATIVE FLOWS FOR LIKE PERIODS—APRIL TO AUGUST.

	Rain. Inches.	Flow. Inches.	Loss of Rain. Inches.
Rancocas, 1890	19.01	7.92	11.09
Great Egg Harbor, 1890	19.85	8.38	11.49

There had been large draught upon ground-water during this period, which was not replenished at the end of August.

By means of these comparative figures we are enabled to establish the relation of flow of the Rancocas with that of the Batsto and Great Egg Harbor. The Rancocas and Great Egg Harbor, for 1890, show very nearly the same flow and evaporation for a given rainfall, and the Great Egg Harbor and Batsto show a like resemblance, as we shall see later. This is enough to convince us that the evaporation for the three water-sheds is practically the same. The flow of the Rancocas is that shown by Table No. 58.

Water-supply.—Like the coast streams of southern New Jersey, although the upper portion of the Rancocas is quite free from sediment, it has a brownish color, quite pronounced when the water is seen *en masse*, but scarcely apparent in a small vessel. This color is usually ascribed to the cedar swamps, and is probably of a peaty nature. Cedar swamp water has a slightly aromatic flavor like that of cedar wood, and is highly esteemed by many for its medicinal qualities. Indeed, it is this which has given Brown's Mills, upon the north branch of the Rancocas, a reputation as a sanitarium. This color is rather prejudicial to the water when used for domestic supply, although there is little doubt that it is by no means injurious. The waters of the Rancocas are used for the supply of Mount Holly.

The headwaters above the villages of Pemberton, Vincentown and Medford are naturally good, wholesome gathering-grounds for water-supply. They are wooded and almost entirely uncultivated, and, like other streams of this region, practically no water ever finds its way over the surface, but passing through the sand to the streams, is thoroughly filtered and purified. We estimate the supplying capacity of the North Branch at Mount Holly, without storage, to be 22,900,000 gallons daily. Above Brown's Mills, the water-shed is 26 square miles, and we estimate the dry-season flow of the stream, without storage, to be 4,370,000 gallons daily. This is an extremely flat water-shed, and opportunities for storage are lacking. Mount Misery brook and the North Branch together, at their junction at New Lisbon, drain 106.3 square miles, and will supply, without storage, in the driest season, 17,800,000 gallons daily. The South Branch, above Vincentown, will supply 9,000,000 gallons daily without storage. There are some opportunities for storage upon this water-shed, and perhaps enough to utilize 10 inches per annum. The headwaters of Haynes' creek, above Taunton, issue from the gravel hills near Berlin, and the water is pure and free from the brown color to which we have alluded. Streams of this portion of the State which do not flow through cedar swamps are wonderfully clear, and are known as white-water streams. These headwaters above Taunton and similar streams would afford a water-supply of the best character.

Water-power.—There are no opportunities for mill sites on the tidal portion of the stream. At Mount Holly, we estimate the power of the North Branch for 9 months of the year at 10.2 horse-power per foot fall, and just below the forks of Mount Misery brook, near New Lisbon, it is 7.95 horse-power per foot fall. Between these two points, the total fall is 35 feet, all of which has been improved in the past, but one mill site at Birmingham, with about 5 feet fall, is not at present in use. At Brown's Mills, there is a large mill-pond, which is now used only as a part of the pleasure grounds of that well-known resort. We estimate the available power here at 1.95 horse-power per foot fall. The fall is 9 feet and the pondage sufficient to concentrate the entire flow into working hours, giving double the above-estimated power. At Hanover furnace, we estimate 0.75 horse-power per foot fall. Here, also, there is, or was until recently, a large pond, and the fall is 10 feet. This is the site of an old charcoal blast furnace, with grist and saw-mill, and the power is not at present in use.

Mount Misery brook, at New Lisbon, will give for 9 months 5.6 horse-power per foot fall, and about 9 feet fall could be developed, or 15 feet by eliminating the power at Lower Mill. At the site of the old Mary Ann furnace there is 8 feet fall not at present in use. The water-shed is 38 square miles, and the available power 2.85 horse-power per foot fall. Just above this, at Mount Misery, a saw-mill was erected as early as 1723. Indeed, many of the sites on the Rancocas date back to about the beginning of the 18th century, and one as early as 1680. An important power was built at Pemberton in 1752 to operate a forge, saw and grist-mill.

The south branch of the Rancocas has an undeveloped fall of about 6 feet below the mill at Eayrstown. By including the Eayrstown mill-site, a total of 14 feet fall could be obtained. We estimate the available power below the mouth of Haynes' creek at 10.4 horse-power per foot fall, so that at this site 145 horse-power for 9 months of the year, or 59 horse-power at all times, could be obtained with sufficient pondage to make twice this amount available for 12 hours per day. At Eayrstown, the water-shed being 62 square miles, we estimate 4.65 horse-power per foot fall for 9 months, and at Vincentown 4 horse-power per foot fall. Just above the present mill-site at this place 10 feet fall could be improved.

Haynes' creek has below the lowest mill nine or ten feet fall unimproved, and we estimate the available power at 5.77 per foot fall. There is no undeveloped fall suitable for any considerable amount of power above this point.

PENSAUKEN CREEK.

This creek drains 35.4 square miles. The water-shed is populous and highly cultivated, and the stream is tidal for about half of its length, consequently it has little importance. Moorestown is supplied from its headwaters, but the quality of the water is said to be unsatisfactory. The average flow at the mouth of the stream is 34,900,000 gallons daily, and the least monthly flow 5,900,000 gallons daily.

COOPER'S CREEK.

This stream rises in the gravel hills north of Berlin, and flows northwest 12 miles to the Delaware at Camden. It is tidal to the forks at Haddonfield, and the lower portion of its water-shed is populous and highly cultivated. Above Haddonfield both branches are more wooded, but there are outcrops of marl upon both. We estimate the average flow of the creek at Camden at 40,000,000 gallons daily, and the flow for the driest month at 6,800,000 gallons daily. Above the pond at Haddonfield the flow for the lowest month is at the rate of 3,050,000 gallons daily, and with storage amounting to 3.28 inches it will furnish 8,600,000 gallons daily.

The only part of Cooper's creek which is worthy of serious consideration as a source of water-supply is North Branch. Its watershed is 11.7 square miles, and the flow for the driest month 1,960,000 gallons daily, or with 3.28 inches storage it will yield 5,660,000 gallons daily. The opportunities for storage are very good, but, like all other streams with marl outcrops, it should have careful inspection before being adopted as a source of supply.

The North Branch is almost entirely undeveloped for water-power purposes. Near Ellisburg, 20 feet fall could be readily obtained, and the available power for 9 months would be 0.87 horse-power per foot fall. As good pondage could be obtained, this would give about 35 horse-power for 12 hours daily during 9 months of the year. On the main creek, at Haddonfield mills, we estimate 1.35 horse-power per foot fall day and night for 9 months. A corn-mill was erected on this site as early as 1697.

TRIBUTARIES OF THE DELAWARE—CAMDEN TO BRIDGETON.

This class of streams are distinguished by being tidal for more than half their total length, which averages about 15 miles. They generally flow through U-shaped ravines, the bottom of which is marshy. The lower portion of the water-shed is usually a very low, level plain of sandy loam, and the headwaters are in the sands and gravels of the Tertiary formation. Owing to the small water-shed

TABLE No. 59.

Flow of Tributaries of the Delaware—Camden to Bridgeton.

	December.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	Year.
AVERAGE YEAR.													
Inches of rainfall	3.72	3.62	3.44	3.72	3.62	4.04	4.04	4.22	4.58	3.72	3.44	3.72	45.88
Inches flowing off	*1.70	2.90	2.71	2.75	2.22	1.92	1.13	.87	.79	.78	.84	1.00	19.61
Flow in thousand gallons daily per square mile	952	1,625	1,620	1,540	1,280	1,070	655	487	442	452	471	579	933
Horse-power on one foot fall per square mile	.168	.286	.285	.271	.226	.189	.115	.086	.078	.079	.083	.102	.165
ORDINARY DRY YEAR.													
Inches of rainfall	4.04	4.12	1.71	3.02	2.67	3.44	3.82	4.55	4.00	1.01	2.14	2.28	36.80
Inches flowing off	3.11	3.35	1.17	2.13	2.05	1.33	.96	.85	.72	.46	.38	.47	16.98
Flow in thousand gallons daily per square mile	1,740	1,870	700	1,190	1,185	745	555	532	403	266	213	272	808
Horse-power on one foot fall per square mile	.307	.330	.123	.210	.209	.131	.098	.084	.070	.047	.037	.048	.143
DRIEST PERIOD.													
Inches of rainfall	4.05	3.66	4.76	3.83	.61	2.71	3.87	.96	1.18	.94	3.04	2.02	31.63
Inches flowing off	3.10	2.93	3.87	2.85	1.46	.91	.84	.46	.30	.30	.30	.30	17.62
Flow in thousand gallons daily per square mile	1,735	1,640	2,315	1,595	845	510	486	257	168	173	168	173	837
Horse-power on one foot fall per square mile	.306	.289	.406	.281	.149	.089	.086	.045	.030	.031	.030	.031	.148
Continued.													
Inches of rainfall	2.63	4.57	4.22	3.57	2.12	5.06	1.90	1.37	6.40	12.09	1.32	.99	46.24
Inches flowing off	.30	.47	.87	1.46	1.66	1.45	.96	.58	.40	2.32	1.63	.98	13.08

*The ground-water is depleted at the end of the average year 1.12 inches, and this is deducted from the December flow.

To utilize 10 inches per annum, or 476,090 gallons daily per square mile, we shall need 3.28 inches storage, or 57,000,000 gallons per square mile. For 9 months of the ordinary dry year, we have available .070 horse-power on one foot fall for each square mile of water-shed.

above the head of tide, they have but little importance for water-power purposes. Another peculiarity of this district is, that it is the one showing the least difference between the average rainfall and average evaporation, as may be seen by consulting the small table at the end of Table No. 46. The average flow-off of these streams is, consequently, smaller than that of any other class in the State. For the driest period, they show about the same results as other southern New Jersey streams. Their rate of flow per square mile of water-shed is shown in Table No. 59.

BIG TIMBER CREEK.

This stream rises near Cross Keys and flows north-northwest to the Delaware river, at Gloucester, its total length in a straight line being 13 miles. It drains 59.3 square miles and is tidal to Good Intent, or about half its total length. The North Branch, above Clementon, and the main stream, above Grenloch, have sandy or gravelly water-sheds, and consequently should afford good local water-supplies. We estimate the average flow of the creek at its mouth to be 55,400,000 gallons daily, and in the driest month, 9,980,000 gallons daily.

Water-supply.—Above Clementon, the water-shed of the North Branch is 5.5 square miles, which will yield, in the driest month, 925,000 gallons daily without storage. With 3.28 inches storage, 2,620,000 gallons daily may be obtained. The South Branch, above Grenloch, or Spring Mills, drains 15.5 square miles, and will yield, in the driest month, 2,610,000 gallons daily, or, with 3.28 inches storage, 7,400,000 gallons daily. The portion of the headwaters of Timber creek suitable for water-supply embraces in all 23 square miles, at an elevation of about 40 feet, with a capacity of 14,700,000 gallons daily with storage. Such water-sheds might be utilized to supply some of the towns near at hand, but they should be controlled by purchases of land bordering the streams, as we have indicated in the case of some of the branches of the Rahway. These headwaters, while they are naturally quite secure from contamination, partake of some of the acid character of southern New Jersey streams, although generally in a less degree. They are usually free from the brown color of cedar swamp streams.

Water-power.—The power of Big Timber creek is well utilized, although the fall is not large At Grenloch, we estimate 1.08 horse-power per foot fall for 9 months. The only undeveloped site of any importance seems to be near the upper bridge at Chews Landing, on the North Branch, where 30 feet fall and good pondage could be had, although this would destroy the power at Laurel mills. We estimate for this point 1.35 horse-power per foot fall, which would give, on 30 feet fall, 40 horse-power day and night, or 80 horse-power for 12 hours during 9 months of the year, with a minimum of 34 horse-power for 12 hours.

MANTUA CREEK.

Rising east of Glassboro this stream runs 13 miles northwesterly to the Delaware at Paulsboro. It drains 51.2 square miles, and above Hurffville it has a gravel water-shed, but below it lies upon the marl region, like other streams of this class. Woodbury is supplied from its headwaters. The report of the water department of 1893 mentions some complaints of bad taste and odor at a time when the reservoir was frozen over, but the water was then examined by chemists and pronounced free from danger. We also note that the boilers at the pumping station were corroded, and had to be renewed at that time. The works were built in 1886. We are not advised as to whether this corrosion was due to the water.

Above Hurffville the water-shed is 13 square miles, and we estimate the flow for the driest month at 2,180,000 gallons daily. With 3.28 inches storage 6,400,000 gallons daily could be obtained. Above the pond near Pitman Grove, Chestnut branch has 4.4 square miles of drainage, and we estimate the daily flow for the driest month at 740,000 gallons, while 2,090,000 gallons daily could be obtained with storage. While there may be some other small branches which would afford good supplies of a limited amount, the rest of the water-shed is open to suspicion, and should not be accepted without careful examination.

The stream does not offer large opportunity for the development of water-power, but near Mantua it would seem possible to develop 20 feet of fall with excellent pondage. We estimate for this point an available power of 2.3 horse-power per foot fall day and night.

RACCOON CREEK.

This is the next stream south, of any size or importance. Rising 3 miles southwest of Glassboro it flows 15 miles northwesterly to the Delaware at Bridgeport. It is navigable to Swedesboro, and tidal for more than half its length. As its water-shed is almost entirely upon the marl region, it is not worthy of serious consideration as a source of water-supply, although some smaller branches with sandy or gravelly water-sheds and free from marl outcrop might be entirely unobjectionable. The water-powers developed are generally small, and the only opportunity for further development is at the first bridge above Swedesboro, where 20 feet fall could be obtained without interfering with existing mill-sites. The available power here would be 1.64 horse-power per foot fall, making 32.8 horse-power continuous, or 66 horse-power for 12 hours, with a minimum of 28 horse-power for 12 hours.

OLDMANS CREEK.

This stream rises close to the source of Raccoon creek, and flows 16 miles west-northwest to the Delaware river. It is tidal for more than half its length. Above the mill-pond at Harrisonville the water-shed is sand or gravel and nearly half wooded, so that it would afford a good gathering-ground. The area of this portion is 10 square miles, and the daily flow for the driest month 1,680,000 gallons, which could be raised to 4,760,000 gallons daily with storage. There is still some undeveloped fall for water-power below Harrisonville, but the power of the stream is small.

SALEM CREEK.

This stream rises near Pittsgrove and flows west-northwest 14 miles, and when within about two miles of the Delaware it turns southward and flows, by a meandering course, a distance of 8 miles measured in a straight line, nearly south, to the Delaware at Salem. At the point where it turns south it is connected with the Delaware by a navigable canal built first about 1800. This canal has a length of 2.02 miles, is 100 feet wide at the surface of the water, 75 feet wide at the bottom, and 5 feet deep. The creek is navigable to

Sharptown, within 8 miles of its source, which is also the head of tide.

Water-supply.—Above Woodstown the water-shed is sandy or gravelly, the portion below being upon the marl region. Above Eastlake the stream drains 14 square miles, with a daily flow of 2,350,000 gallons during the driest month, which could be increased to 6,660,000 gallons daily with storage. There is a good deal of forest on this upper portion of the stream.

Water-power.—At Sharptown, the lowest mill-site on the stream, we estimate for 22.6 square miles drainage 1.6 horse-power per foot fall for 9 months, and at Eastlake 1 horse-power per foot fall. There is about 12 feet fall unimproved between Sharptown and Woodstown, and this is practically the only undeveloped site.

Drainage.—There is a large area of tidal marsh upon the lower portion of the creek, much of which has been successfully embanked and cultivated. This improvement began as early as 1700. Of 31,780 acres of tide marsh in Salem county, 15,225 acres have been improved in this way, and the most of this is along Salem creek. This improvement has been greatly to the advantage of the appearance of this part of the county. As these meadows are at or slightly above the level of high tide, and the rise and fall of the tide is six feet, they have only to be embanked to keep out the water at high tide, and provided with tide sluices, so that between mean and low tide they may discharge the water which falls upon them, and the drainage is effected in this way without pumping. After being embanked and drained for some years these meadows shrink or settle some three or four feet in places, and the banks are then cut and the meadows allowed to be flooded for a period of years. The sediment collects upon them quite rapidly, and in this way they are restored to their original fertility and value.

ALLOWAYS CREEK.

This stream rises near Daretown, close to the headwaters of Salem creek, and flows west-southwest 16 miles to the Delaware, entering opposite Reedy island, which is generally regarded as the head of Delaware bay. It is tidal above Quinton, or for about half its length, and this lower part traverses, by a sinuous course, a very low, level plain. The entire water-shed lies upon the Tertiary sand and gravel.

Water-supply.—Above Alloway pond, the stream drains 21.9 square miles and has a daily flow of 3,680,000 gallons during the driest month, which could be increased to 10,400,000 gallons with storage. This portion of the water-shed is well wooded. Deep run and some other small branches also afford good gathering-grounds.

Water-power.—At Alloway, we estimate 1.53 horse-power per foot fall, and, as the pondage is large, this is all concentrated in 12 hours daily. There is little opportunity to develop any excepting very small powers upon this water-shed.

STOW CREEK.

This stream rises in the wooded gravel hills of the eastern part of Salem county and flows southwest and south to Delaware bay, the source being only 10 miles in a direct line from the mouth. It is tidal for more than half its length and drains a total of 42 square miles, all of which is on the Tertiary formation. It has little importance, although its headwaters are well adapted for local supply if they should ever be needed.

COHANSEY CREEK.

Rising near the headwaters of Alloways creek, in Salem county, this stream flows for 13 miles nearly due south to Fairton and thence west 8 miles to Delaware bay. The city of Bridgeton is at the head of tide and navigation, 9 miles in a direct line from the mouth, but following the windings of the creek, the distance is 19 miles. The stream drains 105.4 square miles, and above the head of tide, at Bridgeton, 45.8 square miles. This embraces an agricultural region, about 13 per cent. being in forest, but this area is decreasing and the cultivated area increasing. Table No. 59 applies to the flow of the Cohansey.

Water-supply.—The headwaters of the stream above Cedar Grove are well wooded, especially near the streams, and would probably be fairly well suited to be a source of water-supply. The area drained is 19 square miles, and we estimate a daily flow of 3,190,000 gallons in the driest month, or 9,000,000 gallons with storage. Bridgeton draws its supply partly from wells and partly from a branch at Eastlake, draining 6 square miles. We estimate a daily flow of 1,800,000 gallons for the driest month. The lake affords some storage. Little creek, above the pond at Fairton, has a sandy and well-wooded water-shed of 8 miles, for which we estimate a daily flow during the driest month of 1,344,000 gallons, which could be increased to 3,808,000 gallons with storage. Such supplies as these, and that afforded by some other branches of the Cohansey, might well be secured and controlled in their present desirable condition in view of the gradual disappearance of forests and increasing cultivation of this region.

Water-power.—There is a good water-power improvement at Bridgeton, consisting of a dam across the Cohansey, raising the water some 19 feet, and a raceway 1 mile in length. One hundred and ninety-five gross horse-power is improved here, the fall being from 14 to 16 feet. We estimate 3.2 horse-power per foot fall continuous, or twice this for 12 hours, available for 9 months. At Cedar creek, we estimate 1.33 horse-power per foot fall continuous during 9 months. There is still 20 feet fall unimproved above the Bridgeton water-power, which would give about 100 horse-power for 12 hours daily during 9 months of the year.

COAST STREAMS.

The Atlantic slope of southern New Jersey has a width of from 20 to 40 miles, while much of the Delaware slope is not more than 15 miles wide, consequently the coast streams are, as a rule, much larger and more important than the tributaries of the Delaware. The tidal portions of these streams are about the same length as upon the Delaware branches, consequently the area of water-sheds above the head of tide is much larger and the streams are, consequently, of greater economic value. The average rainfall of this coast district is also heavier than that of the Delaware slope, while evaporation is at the same rate, consequently the average flow per square mile is larger. These streams are distinguished further by being everywhere bordered by cedar swamps, the growth of which is very dense. The bottoms of these swamps consist, for a great depth, of fallen logs, between which is an accumulation of deep mould and mosses, the whole forming a great absorbent sponge, well calculated to retain large quantities of water to be fed out gradually to the streams. The uplands are everywhere sandy, with very small areas of cultivated land, the timber being mostly pine, but often with a considerable growth of oak brush. This forest is not at all dense, and generally the sun has quite free access to the surface of the earth—still more so as the area is being constantly burned over by forest fires.

The consequence of these conditions is, that water flowing over the surface of the earth is practically an unknown phenomenon, unless when, very rarely, the ground happens to be covered with a coating of ice. As a rule, the whole water, even in quite heavy rainfalls, is stored in the sand and swamps and gradually fed out to the streams. It follows that the dry-season flow is much better sustained than upon any other class of streams with which we have dealt. The quite general brown color of this water is probably also due to these cedar swamps. This color is quite noticeable in the streams and ponds, and it appears to be, to a considerable extent, due to peaty matter in fine particles in suspension. We have mentioned, in the case of the Rancocas, the entirely wholesome character of this water despite this color. A few of the smaller branches of these streams which are not bordered by cedar swamps, but flow directly out of the sand, are remarkably clear and limpid, and are known as white-water. As we shall see when we take up the chemical composition of these waters, they are all slightly acid.

In Plate VI. will be found two curves of storage-flow for these streams. The lower curve is based upon the flow of the Rancocas, and is adapted to those streams, having very flat water-sheds or lacking a large amount of swamp-storage. The curve showing high flow is generally applicable to the larger streams, and we are disposed to attribute this higher flow largely to the swamp-storage, and the sudden dropping off of this flow when the depletion has reached about five inches is believed to mark the point where the swamps have become drained of their water. The great depth to which they are sometimes thus drained is evidenced by the burning down of forest fires when a swamp takes fire in very dry weather. These fires often burn to a depth of several feet, and yet, in a very wet time, the same swamps are almost impassable because of water. Table No. 61 is based upon the high curve of storage-flow which is derived from the gaugings of Great Egg Harbor river, and is adapted to the water-sheds having the higher relief or larger areas of swamp, while Table No. 60 is

A CEDAR SWAMP.

TABLE No. 60.

Flow of Coast Streams with Moderate Ground-Storage.

	December.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	Year.
AVERAGE YEAR.													
Inches of rainfall	3.97	3.88	3.69	3.97	3.88	4.32	4.32	4.53	4.91	3.97	3.69	3.97	49.10
Inches flowing off	*2.56	3.13	2.93	2.96	2.44	1.98	1.18	.88	.83	.83	.88	1.28	21.88
Flow in thousand gallons daily per square mile	1,435	1,750	1,750	1,655	1,415	1,110	684	493	465	482	493	742	1,040
Horse-power on one foot fall per square mile	.253	.309	.309	.292	.249	.195	.120	.087	.082	.084	.087	.130	.184
ORDINARY DRY YEAR.													
Inches of rainfall	4.29	4.38	1.82	3.21	2.83	3.65	4.07	4.84	4.26	1.16	2.26	2.43	39.20
Inches flowing off	3.31	3.60	1.27	2.30	2.10	1.45	1.01	.99	.78	.55	.44	.57	18.37
Flow in thousand gallons daily per square mile	1,850	2,020	760	1,285	1,215	810	585	552	436	318	246	331	875
Horse-power on one foot fall per square mile	.327	.355	.134	.227	.214	.143	.103	.097	.077	.056	.043	.058	.154
DRIEST PERIOD.													
Inches of rainfall	4.05	3.66	4.76	3.83	.61	2.71	3.87	.96	1.18	.94	3.04	2.02	31.63
Inches flowing off	3.10	2.93	3.87	2.85	1.46	.91	.84	.46	.30	.30	.30	.30	17.62
Flow in thousand gallons daily per square mile	1,735	1,640	2,315	1,595	845	510	486	257	168	173	168	173	837
Horse-power on one foot fall per square mile	.306	.289	.406	.281	.149	.089	.086	.045	.030	.031	.030	.031	.148
Continued.													
Inches of rainfall	2.63	4.57	4.22	3.57	2.12	5.06	1.90	1.37	6.40	12.09	1.32	99	46.24
Inches flowing off	.30	.47	.87	1.46	1.66	1.45	.96	.58	.40	2.32	1.63	.98	13.08

*The depletion at end of average year being 0.44 inch, this is deducted from December flow.

To utilize 12 inches per annum, or 570,938 gallons daily per square mile, 4.95 inches storage, or 87,000,000 gallons per square mile, will be needed. Although by the table such reservoirs would not fill in 19 months from beginning of draught, it is believed that because of the severity of our dry season, when applied to this region of large rainfall, 12 inches would be practically available at all times. Available power for 9 months, .077 horse-power on one foot fall for each square mile.

TABLE No. 61.

Flow of Coast Streams with Large Ground-Storage.

	December.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	Year.
AVERAGE YEAR.													
Inches of rainfall	3.97	3.68	3.69	3.97	3.58	4.32	4.32	4.53	4.91	3.97	3.69	3.97	49.10
Inches flowing off	*1.53	2.35	2.93	2.96	2.44	2.03	1.36	1.31	1.23	1.14	1.26	1.34	21.88
Flow in thousand gallons daily per square mile	857	1,370	1,750	1,655	1,415	1,135	787	735	689	660	705	776	1.040
Horse-power on one foot fall per square mile	.151	.231	.309	.292	.249	.200	.139	.129	.121	.116	.124	.137	.184
ORDINARY DRY YEAR.													
Inches of rainfall	4.29	4.38	1.82	3.21	2.83	3.65	4.07	4.84	4.26	1.16	2.26	2.43	39.20
Inches flowing off	3.31	3.60	1.27	2.30	2.13	1.67	1.40	1.31	1.02	.50	.41	.57	19.49
Flow in thousand gallons daily per square mile	1,850	2,020	760	1,285	1,235	935	812	733	572	289	229	330	928
Horse-power on one foot fall per square mile	.327	.355	.134	.227	.217	.165	.143	.129	.100	.051	.040	.058	.164
DRIEST PERIOD.													
Inches of rainfall	4.05	3.66	4.76	3.83	.61	2.71	3.87	.96	1.18	.94	3.04	2.02	31.63
Inches flowing off	3.10	2.93	3.87	2.85	1.68	1.34	1.26	.42	.30	.30	.30	.30	18.65
Flow in thousand gallons daily per square mile	1,735	1 640	2,315	1,595	972	750	731	235	168	173	168	173	888
Horse-power on one foot fall per square mile	.306	.289	.406	.281	.171	.132	.129	.041	.030	.031	.030	.031	.156
Continued.													
Inches of rainfall	2.63	4.57	4.22	3.57	2.12	5.06	1.90	1.37	6.40	12.09	1.32	.99	46 24
Inches flowing off	.30	.40	1.29	1.40	1.44	1.43	1 33	.49	.34	1.32	1.67	1.38	12.79

*Depletion at end of average year being 2.25, this decreases December and January flow.

The ordinary dry year shows 5 51 inches draught on natural storage at the end of November, consequently if two such years occurred in succession, the second would only yield 13.98 inches.

To utilize 12 inches per annum, or 570,938 gallons daily per square mile, 4.68 inches storage, or 81,330,000 gallons per square mile, will be needed. As our assumption of rainfall during the driest period is a severe one for this region of large rainfall, we believe this amount may be safely collected. To collect 9 inches, 2.93 inches storage will suffice, and reservoirs will fill the twelfth month. Horse-power available 9 months of ordinary dry year is 0.1 horse-power on one foot fall for each square mile of water-shed.

TABLE No. 61 A.

Applicable to Large Water-Sheds.

FLOW OF COAST STREAMS DURING DRIEST PERIOD, DETERMINED BY AN AVERAGE OF RAINFALL AT PHILADELPHIA AND VINELAND, DECEMBER, 1880, TO NOVEMBER, 1882.

	December.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	Year.
Inches of rainfall	5.78	5.24	5.18	4.55	.96	3.12	4.22	1.96	.92	1.64	3.08	2.55	39.20
Inches flowing off	4.64	4.34	4.25	3.49	1.55	1.41	1.33	1.32	.42	.30	.30	.30	23.65
Flow in thousand gallons daily per square mile	2,600	2,430	2,545	1,955	900	790	770	740	235	174	168	174	1,125
Horse-power on one foot fall per square mile	.457	.427	.446	.344	.138	.139	.136	.130	.041	.031	.030	.031	.198
Continued.													
Inches of rainfall	2.93	5.51	4.82	3.94	2.16	5.12	1.63	1.80	7.85	12.22	1.54	.99	50.51
Inches flowing off	.30	1.02	1.45	2.29	1.89	1.74	1.38	.75	.57	2.65	1.83	1.42	17.29

FLOW DETERMINED BY AVERAGE OF PHILADELPHIA AND VINELAND RAINFALL, DECEMBER, 1884, TO NOVEMBER, 1886.
(SEE REMARKS BELOW.)

	December.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	Year.
Inches of rainfall	4.90	3.30	3.29	.80	2.31	3.57	1.02	1.84	5.96	.89	4.58	3.67	36.13
Inches flowing off	3.86	2.52	2.57	1.78	1.51	1.44	1.24	.32	.30	.30	.30	.70	16.94
Continued.													
Inches of rainfall	3.17	3.98	5.28	3.49	2.61	4.67	2.52	5.35	2.95	1.22	2.38	3.86	41.48
Inches flowing off	1.26	1.36	2.55	2.54	2.06	1.76	1.47	1.34	1.08	.44	.39	.74	16.99

During the above dry period, in order to utilize 14 inches per annum, or 666,094 gallons daily per square mile, we shall need 4.36 inches storage, and reservoirs will be drawn down 16 months. We recommend that in actual practice 5 inches storage be provided.

Table No. 61 should be used for water-sheds less than 100 square miles in extent, but this is believed to be perfectly safe for those exceeding this area, from the fact that if droughts so severe as that of the Philadelphia record in 1881–2 ever occur in this region they are restricted to one rainfall station and are strictly local.

The second period of small rainfall is given above to show that while the yearly rainfall and flow were less than for the first, the distribution was such that less storage would have been necessary to utilize 14 inches per annum than for the period adopted.

based upon the curve of lighter storage-flow adapted to streams without swamp-storage.

The assumption that the rainfall during the driest period will be as low as that shown by the Philadelphia record during 1881 and 1882, is perhaps too severe to apply to all of the larger water-sheds of this coast region. Our conclusion in the chapter on rainfall was, that any station would be subject to droughts as severe as that shown in the Philadelphia record, yet an examination of the records during these dry periods shows that no two stations, taken together, show any such severe drought. On the other hand, our Sudbury records are proof that an area of 75 square miles was actually subject to as severe a drought during 1882 and 1883. The region which we have now under consideration, however, is one of large rainfall. A study of the records indicates that this large rainfall begins at the inner edge of the tide-meadows along the seashore, where the land generally rises quite abruptly from 30 to 60 feet, or even higher, this height being increased by a pine forest to about 100 feet. At about this line, as we have said, there seems to be quite a rapid increase of rainfall as we move westward, and going still further inland, the rainfall gradually becomes lighter again. Under the conditions which exist, it does not seem probable that any drought so severe as that of the Philadelphia record can extend over an area as large as 100 square miles. In consequence of these facts, we have taken the average rainfall at Vineland and Philadelphia together during the dry years of 1881 and 1882, and again during 1885 and 1886, and computed the flow on this basis. The results are shown in Table No. 61 A. While the total rainfall and total flow-off are much less for the period from December, 1884, to November, 1886, than for the previous one, we find, nevertheless, that the period in 1881 and 1882 embraced the longest series of dry months, and we have adopted this as representative of the driest period applicable to water-sheds of over 100 square miles in extent, but for small water-sheds Table No. 61 should be used.

MAURICE RIVER.

Although this stream empties into Delaware bay, it lies upon the Atlantic slope, and has the climatic, topographic and geological features of the other coast streams, with which it has in consequence been grouped. It rises near Glassboro, flowing due south 33 miles

THE WASTE-WEIR AT MILLVILLE, MAURICE RIVER.

to the Delaware bay. It is navigable and tidal to Millville, 24 miles from its mouth, following the windings of the river, with a depth of about 7 feet at low water. There is a bar across the mouth of the river, but inside of this the channel is for much of the way 20 feet deep. This river is the rendezvous of a large fleet of oyster schooners which work the beds in Maurice cove. The entire area drained is 386.4 square miles, and above the head of tide, at Millville, 218.4 square miles. Sixty-seven per cent. of the area was forested in 1886, but this area is gradually decreasing with the clearing up of farms about Vineland. Table No. 61 applies to the flow of this stream, although for the small branches of less than 10 square miles of drainage area we would recommend the use of Table No. 60.

Water-supply.—The city of Millville is supplied from the large pond on the river at that place, and the water is pronounced satisfactory. It is used without treatment. We estimate the least monthly flow at Millville at 36,700,000 gallons daily, and with 3.11 inches storage, 125,000,000 gallons daily could be obtained. The pond at Millville affords about one inch storage upon the water-shed, and if utilized for storage would maintain the flow at 0.45 inch monthly in the driest time, furnishing 55,900,000 gallons daily. There would be no difficulty in procuring storage to the amount of 4.68 inches if it should be needed. Many of the branches of the stream would afford wholesome supplies, but all the data necessary to determine their supplying capacity will be found in Appendix II., and the tables of flow herewith.

Water-power.—The plant of the Millville Manufacturing Company is one of the finest water-power plants of the State. A pond 926 acres in extent is formed by a dam of earth about 12 feet wide on top and with slopes of about one and one-half to one, with a masonry overfall and timber apron. The water is raised by this dam 26 feet, and the length of the structure is 2,200 feet. This is the largest entirely artificial body of water in the State. A draught of 4 feet upon this pond will afford 0.32 inch storage on the water-shed, and in consequence the power is an exceptionally good and steady one. By Table No. 61, we estimate the power available for 9 months to be 21.8 horse-power per foot fall day and night. The minimum power would be 6.55 horse-power per foot fall, and the entire flow can be concentrated into working hours, or 60 hours per week. With the above pondage, however, the power can be maintained at 13.1 horse-power per foot fall, or 26.2 horse-power for 12 hours daily for every day of the ordinary dry year. The fall is about 22 to 24 feet. In the Census Report of 1880, it was stated that 690 gross horse-power was in use and said to be available for 10 or 11 months of the year. In Appendix I. will be found the amount of power at present in use. Supplementary steam-power, amounting to about 300 horse-power, is in use in the cotton factory and bleachery. There is no doubt that to this water-power is to be attributed at least a part of the great prosperity of Millville during recent years.

At the first bridge above Millville, although the site is not so advantageous, by a somewhat similar development, 24 feet fall could be improved with 194 square miles of water-shed. We estimate 19.4 horse-power per foot fall available here day and night for 9 months of the year, and a minimum of 5.8 horse-power per foot fall. At Willow Grove, the water-shed is 80 square miles, and the table gives 8 horse-power per foot fall for 9 months of the year. Above the site previously mentioned, and near the crossing of Landis avenue, 17 feet fall could be improved with an available power of 11.4 horse-power per foot fall. In Appendix I. will be found a list of powers above Willow Grove, all of which are good ones, although considerably smaller than those we have previously mentioned.

On the west branch, or Muddy run, the drainage above the pond at Rosenhavn is 53 square miles, and the available power 5.3 horse-power per foot fall. At Centreton it is about 42 square miles, giving 4.2 horse-power per foot fall. There are several good small powers on this stream. At the site of the old Buckshutem forge, there is 9 feet fall, with large pondage and about 32 horse-power for 12 hours a day during 9 months of the year. This site is not at present in use.

Manantico creek is tidal up to Clark's mills. This is an abandoned site with 6 feet fall and 3.9 horse-power per foot fall, with fair pondage. This stream rises in, and flows through the wilderness lying between Millville and Mays Landing. In the past, there have been two or three saw-mill sites above this, but the power is not large. Manumuskin creek will furnish at Fries' mill 3.54 horse-power per foot fall. There is good pondage and 8 feet fall, so that probably 56 horse-power can be had during working hours for 9 months. At the old Cumberland furnace site, above, there is a large pond and 9 feet fall, giving 3.16 horse-power per foot fall for 9 months of the year.

Drainage.—The tidal portion of the river flows through a belt of tide marsh about a mile in width, and considerable areas of this have been embanked and cultivated. We are informed that this improvement was very profitable, and that the possession of a proper amount of improved meadow would add from 50 to 100 per cent. to the value of the neighboring farms, as they afford excellent grazing, enabling the farmers to keep cattle, which it is almost impossible to do profitably on the uplands. It is said that 55 bushels of wheat per acre was raised on some of this improved meadow, and that it is adapted to all kinds of grain and hay, and will pay interest on $300 per acre. It is said to sell at from $100 to $150 per acre when in good condition. A considerable part of the banks has recently been allowed to fall into bad repair, owing to disagreements among the owners.

STREAMS OF CAPE MAY COUNTY.

With the exception of Tuckahoe river, which forms its northern boundary, this county is destitute of streams of large size, but some small ones have been thoroughly utilized. In consequence of a scarcity of water-power during the period in the past when steam-power was less generally used than at present, the inhabitants had recourse to tide-mills and wind-mills to a much greater extent than elsewhere in the State. There is a tide-mill still in existence at Dennisville and one at Cold Spring, another near Tuckahoe being abandoned. The 1850 edition of Gordon's map shows also one at Palermo, near Beesley's Point. This map shows four wind-mills along the seashore road, and two on the bay shore. One of these near Seaville was still standing about 1885. Table No. 60 may be applied to the flow of all the streams of this county.

TUCKAHOE RIVER.

This stream rises in the wilderness, 7 miles west of Mays Landing and 16 miles northwest of where it empties into Great Egg Harbor bay. It flows south 9 miles, and then eastward 12 miles. It is tidal and navigable for small craft to head of river, above Tuckahoe. Tuckahoe is 9 miles from the mouth, following the course of the river, but about 6 miles in a straight line. This part of the river flows through a broad area of tide marsh, with no well-defined water-shed line. Above Tuckahoe the drainage area is 60.2 square miles, and above head of river about 30 square miles. By Table No. 60 we find 2.33 horse-power per foot fall at this place. There is now a mill-site with 5 feet fall here. Just below this, at the site of Old Ætna furnace, the water-shed is 37 square miles, and the available power for 9 months 2.9 per foot fall. Ten feet fall could be improved here with good pondage, giving 57 horse-power for 12 hours daily. At Hunter's mill, with about 19 square miles of drainage, 1.5 horse-power per foot fall is available for 9 months. This is an abandoned mill-site, with a good pond and about 5 feet fall.

GREAT EGG HARBOR RIVER.

This stream rises just west of Berlin and flows 38 miles southeast by a very direct course to the head of Great Egg Harbor bay, 5 miles from the seashore. It is navigable and tidal to Mays Landing, 14 miles from the mouth, following the course of the stream. For almost the entire course from the head of tide to the source of the river, the slope is very uniform, rising 5 feet per mile. The branches all converge slowly toward the main stream, and both are bordered everywhere by strips of cedar swamp from one-half to one mile in width, with practically no slope toward the stream. The upland is generally about 40 feet higher than these swamps, and is made up of sand and gravel. About 88 per cent. of the whole water-shed is covered with forest, composed of white cedar in the swamps and a rather sparse growth of pine on the uplands, with oak underbrush. Forest fires through this growth are of frequent occurrence. There are no natural lakes, and practically the only ponds of note are Weymouth mill-pond, having an area of 205 acres and maximum depth of 13 feet, and Mays Landing pond, 333 acres in extent, with a maximum depth of 13 feet, both of which are on the main stream.

The maximum flow observed at Mays Landing from high-water marks and weir computation, gives a flow of 4,756 cubic feet per second, being at the rate of 22 per square mile, and the minimum flow at the same place is 59 cubic feet per second, or 0.27 per square mile of water-shed. Gaugings have been made at Mays Landing, the record having been kept by the courtesy of the Mays Landing Water-Power Company, the results of which are given in the following table. It is instructive to compare these gaugings with a shorter

FLOW OF GREAT EGG HARBOR RIVER AT MAYS LANDING, 1890-2.

Drainage area, 215.8 square miles.

MONTH.	Rain—Inches	Flow—Inches.	FLOW IN CUBIC FEET PER SECOND.		
			Greatest.	Least.	Average.
1890.					
February 16th to 28th	2.40	.86	463	322	383
March	6.06	2.39	723	327	447
April	3.37	2.44	734	268	470
May	3.71	1.88	491	270	348
June	2.33	1.27	352	126	244
July	5.13	1.33	302	201	249
August	5.31	1.46	541	97	273
September	6.06	1.05	366	114	203
October	6.30	1.67	346	270	313
November	.71	1.32	325	142	255
December	4.49	1.52	438	180	284
1891.					
January	6.10	2.88	867	345	542
February	6.22	3.42	781	508	705
March	6.43	4.84	1,043	538	932
April	2.31	2.90	819	324	560
May	3.03	1.67	357	222	313
June	3.33	1.57	343	226	304
July	7.85	1.60	377	154	302
August	5.74	1.67	420	220	313
September	2.12	1.41	404	127	273
October	3.68	1.21	347	126	232
November	2.25	1.24	322	186	290
December	4.30	1.74	370	233	325
1892.					
January	4.98	2.87	628	470	536
February	1.95	1.91	559	311	394
March	6.10	2.11	451	314	395
April	3.22	1.77	424	204	342
May	4.86	2.31	494	332	433
June	2.27	1.21	252	192	233
July	6.35	1.17	352	76	220
August	4.40	1.46	472	104	273
September	1.40	.72	233	48	139
October	.35	.37	85	47	69
November	7.74	.39	56	19	75
December	2.14	1.09	302	95	205

	Rain.	Flow.
June 1890, to May, 1891	54.52	25.33
December, 1890, to November, 1891	53.65	25.93
December, 1891, to November, 1892	47.92	18.03

RAINFALL, EVAPORATION, STORAGE DEPLETION, COMPUTED AND OBSERVED FLOW IN INCHES ON DRAINAGE AREA.

Great Egg Harbor River.

MONTH.	Rainfall.	Evaporation computed.	FLOW OF STREAM.		Depletion computed.
			Computed.	Observed.	
March, 1890	6 06	1.24	4.82	2.39	full.
April	3.37	1.38	1.99	2.44	full.
May	3.71	2.97	1.92	1.88	1.18
June	2.33	3.51	1.38	1.27	3.74
July	5.13	5.17	1.22	1.33	5.00
August	5.31	4.50	.95	1.46	5.14
September	6.06	3.24	1.22	1.05	3.54
October	6.30	1.87	1.43	1.67	.54
November	.71	.83	1.58	1.32	2.24
June to November	25.84	19.12	7.78	8.10	....
December	4 49	.99	1.31	1.52	.05
January, 1891	6.20	1.02	5.13	2.88	full.
February	6.22	1.25	4.97	3.42	full.
March	6.43	1.28	5.15	4.84	full.
April	2.31	1.25	2.00	2.90	.94
May	3.03	2.83	1.52	1.67	2.26
December to May	28.68	8.62	20.08	17.23	....
June	3.33	3.80	1.33	1.57	4.06
July	7.85	6.10	1.30	1.60	3.61
August	5.74	4.62	1.31	1.67	3.80
September	2.12	2.34	1.18	1.41	5.20
October	3.68	1.53	1.13	1.21	4.18
November	2.25	1.00	1.25	1.24	4.18
June to November	24.97	19.39	7.50	8.70	....
Dec, 1890, to Nov., 1891	53.65	28.01	27.58	25.93	....
December	4.30	.97	1.33	1.74	2.18
January, 1892	4.98	.88	1.92	2.87	full.
February	1.95	.57	2.08	1.91	.70
March	6.10	1.24	4.16	2.11	full.
April	3.22	1.36	2.23	1.77	.37
May	4.86	3.24	1.95	2.31	.70
December to May	25.41	8.26	13.67	12.71	....
June	2.27	3.50	1.44	1.21	3.37
July	6.35	5.58	1.31	1.17	3.91
August	4.40	4.24	1.16	1.46	4 91
September	1.40	2.18	.68	.72	6.37
October	.35	1.05	.37	.37	7.44
November	7.74	1.63	1.04	.39	2.37
June to November	22.51	18.18	6.00	5.32	....
Dec., 1891, to Nov., 1892	47.92	26.44	19.67	18.03	....

series on Batsto river for a drainage area of about 69 square miles. It will be found by the following table that the flow-off for these two water-sheds agrees very closely for a given rainfall, notwithstanding the marked difference in the size of the water-shed:

FLOW OF GREAT EGG HARBOR AND BATSTO RIVERS COMPARED.

June to November, 1891—	Rain.	Flow.	Difference.
Great Egg Harbor	24.97	8.70	16.27
Batsto	24.75	8.70	16.05
December, 1891, to May, 1892—			
Great Egg Harbor	25.41	12.71	12.70
Batsto	24.44	11.96	12.48
June, 1891, to May, 1892—			
Great Egg Harbor	50.38	21.41	28.97
Batsto	49.19	20.66	28.53
April, 1891, to March, 1892—			
Great Egg Harbor	47.64	21.90	25.74
Batsto	46.39	20.31	26.08

		EVAPORATION.		
	Rainfall.	Computed.	Observed.	Storage loss or gain.
June, 1891, to May, 1892—				
Great Egg Harbor	50.38	26.90	27.41*	—1.56
Batsto	49.19	26.67	26.97*	—1.56
April, 1891, to March, 1892—				
Great Egg Harbor	47.64	26.37	25.74	....
Batsto	47.39	26.14	26.08	....

* Corrected for loss to ground-water in last column.

In the latter part of this table it will be seen that there is good agreement between the observed evaporation and that computed per square mile, especially for the last period, which is the only one for which we have gaugings on both streams beginning and ending with full ground-water.

As the conditions on these coast streams show the widest departure from the conditions on the Passaic, Croton and Sudbury, it may be well to make a more careful comparison of the results of this series of gaugings with the computed flow for the same period as determined by our formulæ. This we have done in detail in the table following the table of gaugings. This exhibit shows a general excess of computed over observed flow of 12 per cent. from December to May, and a deficiency of 4 per cent. from June to November, with an excess of 8 per cent. for the year; or, if we exclude the first period, for which rainfall data are less satisfactory, the last two years show 7 per cent. excess of computed over observed flow. Some of this is doubtless due to leakage at the point of gauging, but it is mostly to be attributed to the fact that we have adopted a uniform excess of 14 per cent. throughout the year over evaporation shown on the Passaic. The following table has been prepared from the Climatology of New Jersey. It gives first the average yearly and seasonal temperatures for the Red-sandstone Plain and Highlands taken together, as these approximately represent conditions on the Passaic water-shed. Next we give the same data for the southern interior and coast, as these two together represent fairly the region under consideration. It will be seen from this that the difference in evaporation will not be uniform throughout the year as we have assumed, and instead of a uniform rate of 14 per cent. excess over the Passaic evaporation, we should have allowed about 8 per cent. in spring, 11 per cent. in summer, 19 per cent. in autumn and 19 per cent. in winter. Had this been done the above discrepancies would disappear, but since the final result would not be seriously affected we have decided to adhere to the more simple method of applying the even correction throughout the year.

TEMPERATURE BY SEASONS, IN DEGREES FAHRENHEIT.

	Year.	Spring.	Summer.	Autumn.	Winter.
Red Sandstone Plain and Highlands...	49	47.1	69.4	51	28.5
Southern Interior and Coast..............	52.4	48.9	72.1	55.5	33.1
Difference in Temperature.................	3.4	1.8	2.7	4.5	4.6
Difference in Evaporation.................	17%	9%	13.5%	22.5%	23%

The facts brought out by the gaugings, however, are striking evidence of the paramount influence of temperature upon evaporation and the flow of streams, and of the delicacy with which streams respond to slight difference therein.

We are aware of the fact that a more refined and accurate formula for computing evaporation from rainfall and temperature than the one we are using is quite possible. It is more cumbersome in application, however, and requires more accurate temperature observations than are generally available, consequently we have hesitated to introduce or apply it.

Table No. 61 applies to the Great Egg Harbor water-shed, giving safe results everywhere. For portions of the water-shed exceeding 100 square miles we may, for the driest year, apply Table No. 61 A, but such application should be after more careful consideration.

Water-supply.—The water of this stream has the usual brownish color peculiar to its class, but the analysis which we give later indicates a remarkably pure water, although slightly acid. Storage could probably be found sufficient to utilize 14 inches per annum, and while the reservoirs would usually be rather shallow, it is not believed that this would cause any deterioration of the water, judging from present indications. It must be remembered that in this sandy soil a very slight depth of water is usually sufficient to destroy all vegetable growth, and shallow ponds usually keep as sweet and pure as the deeper ones. At Mays Landing the stream drains 215.8 square miles, and we estimate the average flow to be 224,400,000 gallons daily. In the driest year, with storage, the stream will supply 143,800,000 daily. The minimum flow is 36,400,000 gallons daily. At Weymouth, the drainage being 192 square miles, the average flow is 199,000,000 gallons daily, and the minimum 32,250,000 gallons daily. With storage, 128,000,000 gallons daily may be collected. The elevation here is 37 feet. At the highway bridge just below the New Jersey Southern railroad crossing the main stream drains 51 square miles, having a minimum flow of 8,570,000 gallons daily, and a capacity with storage to supply 29,100,000 gallons daily, the elevation being 70 feet.

Hospitality Branch drains 50.5 square miles, having a minimum flow of 8,480,000 gallons daily, and a capacity with storage of 28,800,000 gallons daily, the elevation being 40 feet.

South river, at the site of Monroe furnace, has a minimum flow of 3,190,000 gallons, and with storage will supply 10,830,000 gallons daily. The elevation is 12 feet.

Stephen's creek, at Estellville, has a minimum flow of 1,695,000 gallons daily, and a capacity with storage of 6,000,000 gallons daily.

Babcock's creek, at Mays Landing, including Watering Race, or North Branch, has a minimum flow of 3,965,000 gallons, and with storage will supply 12,100,000 gallons daily.

Water-power.—There is but a small amount of power developed on the Great Egg Harbor, as will be seen by Appendix I. Although the fall is not great, several opportunities exist to develop water-power. The plant of the Mays Landing Water-Power Company, at the head of tide, is a well-equipped one. Power is used to operate a large cotton mill. The fall varies somewhat with the tide, ranging from 10 to 11.5 feet. The dam is of earth, with a substantial stone overfall and a large pond. The wheel plant here has been recently enlarged, but up to 1890, 180 horse-power was in use, and was said to be always obtainable, with a little waste over the dam, the power being used 64 hours per week. This is equivalent to a power of .029 horse-power per foot fall for each square mile of water-shed, entirely harmonizing with our computed flow during the driest period. The present wheel plant being much larger, is not fully supplied with water throughout the year. We estimate the power available for 9 months at 21.6 horse-power per foot fall, and for 6 months, 35.7 horse power per foot fall day and night.

At Weymouth, there are a paper-mill and saw-mill, with 13 feet fall, and 160 gross horse-power is said to be developed. We estimate for 9 months 19.2 horse-power per foot fall, the pondage being good. At the head of Mays Landing pond, 10 feet fall could be developed, with about the same power per foot as at Mays Landing, or 200 horse power in all for 9 months.

Below the mouth of Hospitality Branch, the drainage being 155 square miles, 15.5 horse-power per foot fall is available, and about 15 feet fall could be developed, or 227 horse-power in all. Near the crossing of the New Jersey Southern railroad, on the main stream, we estimate the available power at 5 horse-power per foot fall.

Hospitality Branch, near its mouth, will furnish 5 horse-power per foot fall for 9 months, and 15 feet fall could be developed.

Deep run, at its mouth near Weymouth, will furnish 2.26 horse-power per foot fall, and 20 feet fall could be developed with good pondage, so that 90 horse-power could be used for 12 hours daily.

South river, at Monroe furnace, will furnish 1.9 horse-power per foot fall, and 15 feet fall might be developed. At Estellville,

THE WATER-POWER AT MAYS LANDING.

Stephen's creek has an available power of about 1 horse-power per foot fall on 6 feet fall, or 12 horse-power for 9 months and 20 for 6 months for working hours. Babcock's creek, at Mays Landing, will furnish, for 9 months, 2.1 horse-power per foot fall, and 12 feet fall, with good pondage, could be developed.

PATCONG CREEK.

This is a tributary of Great Egg Harbor bay, at a point just below the mouth of the river. It is about ten miles long in a direct line from source to mouth, and for half its length is tidal. Above the lower mill-pond at Bargaintown it drains 19 square miles, and applying Table No. 60 we find the minimum flow to be 3,200,000 gallons daily. The ponds afford considerable storage, so that more than this amount could be actually drawn. The maximum amount available with storage is 10,800,000 gallons daily.

ABSECON CREEK.

This stream drains, to the bridge at Absecon, 18.3 square miles, and above the lowest mill-pond at the head of tide 12 square miles. Table No. 60 applies, and we find at the lower pond a minimum flow of 2,016,000 gallons daily, and a capacity with storage of 6,850,000 gallons daily.

MULLICA RIVER.

This is the largest stream of the Atlantic coast group. It drains in all 570 square miles, and excepting the Delaware is the third stream in size in the State. It rises near Atco and flows 32 miles east-southeast, measuring in a direct line to the head of Great bay, 6 miles from the sea. It is tidal and navigable for 20 miles, following the very sinuous course of the river. The depth of the channel through Great bay is not much over four feet at low tide, but in the river it increases to about 20 feet, ranging to 40 feet. The lower 7 miles of the stream is bordered by tide marshes, which reach a width of 4 miles near the mouth. Its principal tributaries all converge at Batsto, at the head of tide. They are the Batsto, Atsion, Mechescatauxin, Nescochague and Hammonton brook, embracing a total drainage of 221.6 square miles. This portion of the drainage area is quite similar to that of the Great Egg Harbor in its topographical features. The streams are all bordered by strips of cedar swamp, and they converge slowly as they flow down the gently-sloping plain. Eight miles from the mouth of the river, following the stream, but only half as much in a direct line, it receives its principal tributary from the north, known as Wading river. This stream rises west of Woodmansie, and 22 miles a little west of north from its mouth. It is navigable and tidal about 8 miles, this part of the stream being bordered by a narrow strip of tide marsh. It drains 189 square miles, or one-third of the whole basin of Mullica river. This tributary and its branches are also much bordered by cedar swamp, but this is more disposed in compact and isolated areas than in regular strips along the streams. Less than 10 per cent. of the whole drainage area of Mullica river is cleared, and on Wading river less than 2 per cent., the remainder being forested with cedar in the swamps and a rather sparse growth of pine on the uplands. Some clearing is being done at Egg Harbor City and Hammonton, the cleared areas being brought under cultivation.

FLOW OF BATSTO RIVER AT BATSTO.

Drainage area, 69.7 square miles.

MONTH.	Rain—Inches.	Flow—Inches.	FLOW IN CUBIC FEET PER SECOND.		
			Greatest.	Least.	Average.
1891.					
April	2.24	2.05	287	92	127
May	2.92	1.44	112	70	86
June	3.68	1.17	126	70	72
July	7.12	1.79	197	59	109
August	5.09	1.46	124	64	88
September	2.86	1.62	226	67	101
October	3.76	1.55	131	52	94
November	2.24	1.11	88	55	69
December	4.11	1.42	116	52	85
1892.					
January	4.79	2.38	259	46	141
February	1.99	1.40	111	75	91
March	5.59	2.92	265	107	175
April	3.09	1.70	151	77	131
May	4.87	2.14	168	91	128
June	2.34	.97	111	38	63
July	5.31	1.04	129	42	62
August	4.55	.80	68	34	48
September	1.45	.62	49	31	39

	Rain—Inches.	Flow—Inches.
June to November, 1891	24.97	8.70
December to May, 1892	24.44	11.96
June, 1891, to May, 1892	50.38	20.66
April, 1891, to March, 1892	46.39	20.31

Gaugings have been made of the flow of Batsto river, at Batsto, with the co-operation of Joseph Wharton, Esq., and the accompanying table of flow gives the results of this work. An extended comparison of the results of these gaugings with those for the Great Egg Harbor river during the same period has been made in our discussions of the latter gaugings already given. A more extended and detailed study shows that this similarity extends throughout, so that for a given depletion of ground-water both streams show the same rate of flow per square mile of drainage area, and the same ground-flow curve answers for both. This is the curve on which Table No. 61 is based, which table consequently applies to the flow of the Batsto, and by inference to all other branches of the Mullica, while Table No. 61 A may be safely applied to the larger areas for the driest period.

Water-supply.—The waters of Mullica river, while they have the characteristic brownish color of these southern New Jersey stream waters, have in a marked degree the advantages of uninhabited gathering-ground and perfect natural sand filtration; conditions favorable to great purity and softness. We estimate the average flow of the whole stream into Great bay at 593,000,000 gallons daily, and the minimum flow at 95,800,000 gallons daily.

Batsto river above the dam at Batsto, drains 69.7 square miles. It has an average flow of 72,500,000 gallons daily, with a least flow of 11,600,000 gallons, and a capacity with storage to supply 46,400,000 gallons daily.

Atsion river above the pond at Batsto drains 73.15 square miles and has an average flow of 76,000,000 gallons daily, with a minimum of 12,300,000 gallons. Its supplying capacity with storage we estimate at 48,700,000 gallons daily.

The Nescochague above the dam at Pleasant Mills drains 34.99 square miles. Its average flow is 36,400,000 gallons and its minimum 5,870,000 gallons daily. With storage its supplying capacity is 17,200,000 gallons daily.

The total drainage of the headwaters of the Mullica above Batsto embraces 221.6 square miles, with a total average flow of 230,000,000 gallons and a minimum flow of 37,200,000 gallons daily, and a capacity with storage to supply 147,000,000 gallons daily.

The west branch of Wading river drains 97.12 square miles. Its average flow is 101,000,000 gallons daily and least flow 16,400,000 gallons daily. Its supplying capacity with storage is 64,700,000 gallons daily.

The east branch of Wading river drains 66.45 square miles, and has an average flow of 69,200,000 gallons daily. Its minimum flow is 11,200,000 gallons daily, and with storage it will supply 44,300,000 gallons daily.

Bass river will afford a local supply of considerable amount. Nacote creek above the pond at Port Republic drains 17 square miles, and we estimate its minimum flow at 2,850,000 gallons daily and its supplying capacity with storage at 9,700,000 gallons daily.

Water-power.—There are in all but 14 mill sites at present on this water-shed, whereas in 1850, Gordon's map shows 27 sites, of which

20 were occupied by mills—probably mostly small saw-mills—and 7 by iron furnaces.

Batsto river, at Batsto, has an old furnace site, with 9 feet fall, now occupied by a small grist and a saw-mill. We estimate 7 horse-power per foot fall for 9 months, or 70 horse-hower in all, day and night. There is good pondage, so that probably twice this would be available for 12 hours daily. The Pleasant Mills Paper Company occupy a site with 10 feet fall on Hammonton brook, the Nescochague being diverted into the pond by a raceway and a large storage pond, so that the mill receives water from 53.3 square miles on Hammonton brook and the Nescochague and 73.15 on the Atsion, or 126.5 in all, giving 12.65 horse-power per foot fall for 9 months, but with the large pondage, twice this is available for working hours. At Atsion, on the site of the old Atsion furnace, there is 9 feet fall not at present in use. The drainage area of Atsion river above this point is 25.09 square miles, and the Mechescatauxin has been diverted by a raceway, adding 18.62 square miles, making 43.7 square miles in all. We estimate the power available for 9 months at 4.37 horse-power per foot fall, but as there is good pondage, more than this will be available for working hours.

On the east branch of Wading river, at Harrisia, there is a paper-mill which has recently suspended operations. It has 12 feet fall, and the west branch of Wading river is diverted into the pond by a canal, giving a total tributary water-shed of 155 square miles. We estimate for 9 months 15.5 horse-power per foot fall, or 186 horse-power in all, day and night, the pondage being sufficient to make much more than this available during working hours. At Martha furnace site, just above, on the east branch, or Oswego river, there is an abandoned site with 12.5 feet fall and 64 square miles drainage, giving for 9 months 6.4 horse-power per foot fall day and night. About 2 miles further up, 10 feet fall and 60 horse-power could be developed.

On the west branch of Wading river, 1 mile above where it is diverted to the paper-mill at Harrisia, 15 feet fall could be developed with 90 square miles drainage, giving 9 horse-power per foot fall day and night. At the the old Speedwell furnace site, 8 feet fall is available, and Shoal branch, being diverted to the pond by a canal, the drainage area is about 50 square miles, and 5 horse-power per foot fall, or in all 80 horse-power for working hours could be obtained.

There are large areas of valuable cranberry bogs under cultivation upon the cedar swamp bottoms of Wading river and its branches.

Nacote creek, at the large pond at Port Republic, will furnish 1.9 horse-power per foot fall, 6 feet fall being available. The pondage is large enough to give 23 horse-power for 12 hours daily.

SMALL STREAMS OF OCEAN COUNTY.

In general, Table No. 60 may be applied with safety to all these streams, although in some cases the flow may be as high as that shown by Table No. 61.

Tuckerton creek.—Above the mill-pond at Tuckerton, this stream drains 11.9 square miles, and we estimate a minimum flow of 2,000,000 gallons daily. The capacity with storage is 6,800,000 gallons daily. About 0.9 horse-power per foot fall is the available power for 9 months, the fall being 7 feet with good pondage.

Westecunk creek.—Above the pond at West Creek village this stream drains 21 square miles, and we estimate the minimum flow at 3,530,000 gallons daily. The capacity of the stream with storage is 12,000,000 gallons daily. The power available at this point for 9 months is 1.6 horse-power per foot fall, and the fall being 6.25 feet about 20 horse-power may be had for working hours. There are large cranberry bogs at Staffordville on this stream.

Manahawken creek, or Mill creek.—Above the large pond at Manahawken village this creek drains 19.7 square miles. The pond has an area of 98 acres, and we estimate the minimum flow at 3,300,000 gallons daily. With storage the stream will supply 11,250,000 gallons daily. The power available for 9 months we estimate at 1.5 horse-power per foot fall, and the fall is 8 feet, so that with a large pondage 24 horse-power is easily attainable during working hours.

Forked river.—The north branch of this stream above the village bridge drains 14.7 square miles, and we estimate the average flow at 15,300,000 gallons daily, the minimum flow at 2,470,000 gallons daily, and the capacity with storage 8,400,000 gallons daily. The power available for 9 months is 1.1 horse-power per foot fall, the fall being 8.5 feet at the saw and grist-mill, giving about 20 horse-power for working hours.

Cedar creek.—This stream drains 55.8 square miles above the village bridge, and Table No. 61 may be safely applied, as the stream is bordered throughout by cedar swamps. We estimate the average flow at 58,000,000 gallons daily, the minimum flow at 9,370,000 gallons daily, and the supplying capacity with storage 31,900,000 gallons daily. The power available at this point we estimate at 5.6 horse-power per foot fall for 9 months, and about 15 feet fall could be developed with large pondage, giving 84 horse-power day and night, or 168 horse-power for 12 hours daily.

At Double Trouble saw-mill there is 6 feet fall with large pondage. The drainage being 45 square miles, 4.5 horse-power per foot fall, or 27 horse-power continuous, and twice this for working hours may be obtained during 9 months. Further up the stream there are two good ponds at the site of the old Dover forge and the Farrago forge at Bamber, both of which are now used for saw-mills.

TOMS RIVER.

This stream rises at Clarksburg, near the source of the Assanpink and Millstone, in Monmouth county, and flows southeast to the head of tide at Toms River village, a distance of 20 miles in a direct line. Thence eastward, 5 miles to Barnegat bay, the river extends as a shallow estuary, from 5 to 10 feet deep and about 1 mile wide at the mouth, being practically an arm of Barnegat bay. The water-shed lies almost entirely upon the Tertiary sand and gravel, and has an area of 163.8 square miles. The upper portion resembles the more southerly streams of this group, the water-courses being everywhere bordered by strips of cedar swamp, and the uplands from 40 to 60 feet higher and wooded with the characteristic pine growth of this section. On the lower portion of the water-shed, there is a little variation in the topography. The stream and its branches are bordered by flats half a mile or less in width, from which the uplands rise quite abruptly at first by steep banks about 30 feet high. Further back, the uplands rise from 60 to 80 feet above the stream valley. Only 6 per cent. of the water-shed is cleared of timber.

Table No 61 applies to the flow of Toms river and its branches.

Water-supply.—The water is of the same general character as the other streams of this group. We estimate the total flow at Toms River bridge at 170,000,000 gallons daily during the average year, and the minimum flow at 27,500,000 gallons daily. The whole water-shed has a supplying capacity, with storage, of 112,000,000 gallons daily.

Above the confluence of Ridgeway Branch, the stream drains 58 square miles and has an average flow of 61,400,000 gallons daily, a minimum flow of 9,900,000 gallons daily and a capacity, with storage, to supply 33,750,000 gallons daily.

Ridgeway Branch is the principal affluent and rises near Collier's Mills, on the west line of Ocean county. It flows southeast by east, joining Toms River 3.5 miles above the village. It drains 64.9 square miles and has an average flow of 67,500,000 gallons, a minimum of 10,900,000 gallons and will supply, with storage, 37,200,000 gallons daily.

Union Branch is the principal affluent of Ridgeway, which it joins 2 miles above the mouth. This branch drains 30 square miles and has an average flow of 31,200,000 gallons daily, a minimum of 5,040,000 gallons daily and, with storage, will supply 17,220,000 gallons daily.

Davenport Branch drains 34 square miles. It has an average flow of 35,300,000 gallons, a minimum of 5,720,000 gallons and a capacity, with storage, to supply 19,400,000 gallons daily.

Water-power.—There are at present on this water-shed but 12 mills at 9 mill sites, with an aggregate of 288 net horse-power. In 1850, we find 19 mills and Manchester and Phœnix iron furnaces using power on the stream and its branches. Here, as elsewhere in this portion of the State, this decadence of water-power is due to the exhaustion of the timber-supply, causing the abandonment of saw-mills and to the change of conditions in the iron industry, which caused the abandonment of the small charcoal furnaces. Owing to the configuration of the lower valley, the opportunities for the development of water-power are exceptionally good on this stream. At the crossing of the highway from Toms River to Manchester, a development very similar to that at Millville would furnish 25 feet fall with a pond 4.5 miles long and half a mile wide. The drainage area is 129 square miles, and we estimate the power for 9 months at 12.9 horse-hower per foot fall, or 322 horse-power day and night, which, with the pondage mentioned, would give 644 horse-power for 12 hours daily. This power, in the very driest season, would never fall below 193 horse power for 12 hours daily. Just above the confluence of Ridgeway Branch, the available power of the stream is 5.8

horse-power per foot fall, and 15 or 20 feet fall could be readily developed. At White's bridge, the stream will furnish 4.5 horse-power per foot fall, and facilities are good for developing 15 feet fall.

On Ridgeway Branch, at the site of the old Phœnix furnace, about one mile above the mouth, 6.4 horse-power per foot fall is available, and 15 or 20 feet could be readily developed. At Manchester pond, on Union branch, we estimate 2.1 horse-power per foot fall, there being 14 feet fall with good pondage, so that about 60 horse-power is available for 12 hours daily during 9 months of the year.

On Davenport Branch, at Van Schoick's mill, we estimate 3.4 horse-power per foot fall, or twice this for working hours for 9 months of the year.

It will be seen that Toms river presents exceptionally good facilities for developing water-power, and an aggregate of 1,000 horse-power could be easily obtained.

METEDECONK RIVER.

This is the last of the coast streams as we go northward which has its water-shed wholly upon the Tertiary sand and gravel. The lower 4 miles of the river is a shallow tidal estuary like that of Toms river, having an average width of about half a mile, and really forms the head of Barnegat bay. From the head of tide at Burrsville to the source of the river at Charleston Springs is 16 miles in a direct line, the general course of the river being east-southeast. The river has two branches, which rise close together and alternately recede and approach each other, the distance apart nowhere much exceeding 3 miles, and being in some cases less than one. They do not finally come together until within about a mile from the head of tide. The South Branch flows through Lakewood, and the whole area drained above the head of tide is 73.9 square miles. The relief of the water-shed is considerably bolder than upon the previous streams of this class. The streams are bordered by a very narrow strip of wooded swamp, the aggregate area of swamps being quite small, and the uplands rise in many places with considerable abruptness from 75 to 100 feet above the stream valleys. The uplands are covered with the characteristic pine growth of the Tertiary plain. But 32 per cent. of the whole area is cleared and under cultivation.

Table No. 61 may be safely applied to the Metedeconk.

Water-supply.—The water of the South Branch is used at present to supply Lakewood to the extent of 280,000 gallons daily, all of the water being filtered. We estimate the average flow at Burrsville at 76,800,000 gallons daily, the minimum at 12,400,000, and the supplying capacity, with storage, 42,300,000 gallons daily. The North Branch drains 43.2 square miles, with an average flow of 44,800,000 gallons, a minimum of 7,250,000 gallons, and a capacity to supply 24,600,000 gallons daily, with storage. South Branch, at Lakewood, has an average flow of 25,500,000 gallons daily, a minimum of 4,120,000 gallons and a capacity to supply, with storage, 14,000,000 gallons daily.

Water-power.—At Burrsville there is an old mill-site with 9 feet fall and a large pond. We estimate the power for 9 months at 7.4 horse-power per foot fall, or 66.6 for the fall given, twice this being available for 12 hours daily. The North Branch at Lane's mill will give 3.8 horse-power per foot fall for 9 months, and the same stream at Lakewood 2 horse-power per foot fall, and 10 feet fall could be developed, or 40 horse-power for 12 hours daily during 9 months.

The South Branch, near its mouth, will furnish 2.9 horse-power per foot fall, and 10 feet fall might be improved. At Lakewood we estimate 2.45 horse-power per foot fall. There is 9 feet fall with good pondage, so that 44 horse-power may be had for 12 hours daily during 9 months, or 75 horse-power during 6 months. The power here is used for pumping water and running the electric light plant, the largest use being in winter. At Bennett's mills we estimate 1.8 horse-power per foot fall, and the fall is 9 feet with good pondage, so that 32 horse-power is available for 12 hours daily.

MANASQUAN RIVER.

This stream rises southwest of Freehold, 17 miles from its mouth, and flows southeasterly. From the inlet to the head of tide, a distance of 5.5 miles, is a tidal estuary from one-quarter to one-half a mile in width, with an area of 1,216 acres. Manasquan inlet furnishes a restricted outlet to the sea. This portion of the river is quite picturesque, the topography being much bolder than that of the previous water-sheds. The stream has a well-defined valley along its lower course, about two miles wide and from 100 to 150 feet deep. There is comparatively little swamp and the upper portion of the water-shed is quite highly cultivated, only 32 per cent. of the whole being in forest. The cultivated portion of the water-shed is largely on the marl district, and the stream is in consequence, when swollen, muddier than those more southerly. The whole area drained is 80.5 square miles.

Water-supply.—It will be seen from our description above that the stream is less promising as a source of water-supply than those we have previously described. The average outflow of fresh-water at Manasquan inlet is 83,600,000 gallons daily. At Upper Squan bridge, above the head of tide, the average flow is 67,300,000 gallons daily, and the minimum 10,900,000 gallons daily.

Water-power.—At Upper Squan bridge the stream will furnish during 9 months 6.5 horse-power per foot fall. Thirty feet fall could be developed here with fine pondage, giving 195 horse-power continuous, or 390 horse-power for 12 hours daily. This site is convenient to be used for electric lighting, &c., along the seashore.

SMALL COAST STREAMS OF MONMOUTH COUNTY.

Wreck pond.—This has a water-shed of 12.8 square miles and an average inflow of 13,300,000 gallons daily, the minimum being 2,150,000 gallons daily.

Shark river.—This stream flows into the Shark River bay, which has an area of 1,018 acres, with a restricted and uncertain outlet to the ocean, which is sometimes closed by storms, temporarily. The drainage of the river to the head of the bay embraces 16.9 square miles, of which 59 per cent. is wooded. The average flow is 17,550,000 gallons daily, and the minimum 2,830,000 gallons daily. With storage the stream will supply 9,670,000 gallons daily. There is some marl along the main stream.

The North Branch above the pond at Kisner's grist-mill drains 5.92 square miles. The minimum flow is 990,000 gallons daily, and with storage the stream will supply 3,390,000 gallons daily.

Deal lake.—This lake has an area of 144 acres and receives the drainage from 6.1 square miles, giving an average flow of 6,340,000 gallons and a minimum flow of 1,025,000 gallons daily.

Whale-pond brook.—This stream is used as a source of water-supply for Long Branch. It is reported that 1,000,000 gallons daily is used, the supply being filtered. The stream drains 5.1 square miles, giving an average flow of 5,300,000 gallons and a minimum of 855,000 gallons daily. The maximum available with storage will be 2,910,000 gallons daily. There is already some storage in use.

Shrewsbury river.—This is really a large, shallow, irregular bay, having an area of 2,202 acres above Seabright bridge, and receiving the flow of several small tributaries. The drainage amounts to 29 square miles, and covers a populous and cultivated area. The average inflow of fresh water amounts to 30,200,000 gallons daily.

NAVESINK RIVER.

This stream rises near Freehold and flows 17 miles northeast to Sandy Hook bay. It will be observed that its course is at right angles to the general course of the Atlantic coast streams. The lower 7 miles up to Red Bank is a tidal estuary about three-quarters of a mile wide and 250 acres in extent. The entire drainage area is 95 square miles, and this lies almost wholly in the marl region and is highly cultivated. The water-shed is also populous. Its topography is entirely different from that of the Tertiary water-shed and resembles somewhat that of some of the tributaries of the lower Delaware. The stream and its branches traverse narrow, flat-bottomed ravines, bordered by high banks and are sinuous in their course. Table No. 60 applies to the flow of the Navesink and its branches.

We estimate the average flow into Sandy Hook bay at 98,850,000 gallons daily, not including the Shrewsbury.

Water-supply.—It is sufficiently indicated by the above description that this stream is not fitted to become a source of water-supply, although some of its small branches might afford good local supplies. We estimate that Swimming river, at Red Bank, discharges an average of 68,000,000 gallons daily and a minimum of 11,000,000 gallons daily.

Water-power.—Swimming river affords some good opportunities for the development of water-power in moderate amounts on its upper courses. At Red Bank, a dam 1,300 feet long would develop 30 feet fall with large pondage. We estimate that for 9 months, 5 horse-power per foot fall, or 150 horse-power day and night, and 300 horse-power for 12 hours daily could be obtained, and the minimum flow of the stream would furnish 2 horse-power per foot fall, or 120 horse-power for 12 hours daily.

The water-power at Tinton Falls is one of historic interest. This was the site of Lewis Morris' iron works, established not later than 1682. The drainage of the stream above this point embraces 12.25 square miles, and the fall is 28 feet. For 9 months, 0.94 horse-power per foot-fall, or in all, 52 horse-power for 12 hours daily can be obtained, and for 6 months, 94 horse-power for 12 hours daily is available. It will be seen that this was sufficient for what would be regarded as a good-sized plant at that period.

SMALL BRANCHES OF RARITAN BAY.

These streams lie entirely on the marl region and, in general, are of little economic importance. It is not necessary to take them up in detail. Table No. 60 applies to their flow.

SOME GENERALIZATIONS AS TO WATER-SUPPLY.

LEAST MONTHLY AND MINIMUM FLOW.

We have, in our foregoing estimates, dealt with the average flow of the stream during the driest month. It should be remembered that many streams are likely to fall below this amount for as much as two weeks. In Table No. 42, we have given a list of observed minima for the various streams. We may compare these with the computed average flow during the driest month.

Table No. 51, applying to Kittatinny valley and Highland streams, gives a least monthly flow at the rate of 81,000 gallons daily per square mile. In our remarks following Table No. 42 we conclude that the natural minimum of these streams ranges between 0.10 and 0.15 cubic foot per second per square mile, or 64,627 to 96,940 gallons daily. It is evident, therefore, that on this class of streams, in order to always obtain the rate given as the least monthly flow, a small amount of storage must be provided equal to about 100,000 gallons per square mile.

Table No. 52, applying to such streams as the Pequest, shows a least monthly flow at the rate of 140,000 gallons daily. These streams occasionally fall as low as 97,000 gallons daily, so that storage to the amount of 650,000 gallons per square mile would be needed. The flow of the Passaic is given in Table No. 53 at the rate of 127,000 gallons daily per square mile for the driest month. The least observed is 123,000 gallons daily per square mile, so that storage to the amount of 60,000 gallons per square mile would be needed in order to hold the stream up to the average flow of the driest month. Table No. 54 applies to the Hackensack and northern red sandstone streams with large ground-flow. It gives the flow during the driest month at 123,000 gallons daily, and when allowed to flow naturally it appears from our observations that this class of streams do not fall below this. It may be remarked here that it is the rule with streams of large ground-storage that their flow is more evenly sustained during the dry months, and they do not fluctuate to the extreme low limits of those with more limited ground-flow.

Table No. 55, for the Raritan, gives an average flow during the dry months as low as the lowest flow which has ever been observed.

For the class of stream to which Table No. 56 applies, it will be best to provide storage amounting to 330,000 gallons per square mile in order to obtain the average flow during the driest month at all times, since these streams are likely to run entirely dry during two weeks. The flow of the Delaware is given in Table No. 57 at 127,000 gallons daily per square mile during the driest month, whereas the actual observed minimum is 110,000 gallons daily per square mile, so that 255,000 gallons per square mile of storage should be provided in order to obtain the average flow for the driest month during every day of that month. The southern New Jersey streams all have large ground-storage, and when flowing naturally will always furnish the average daily flow for the driest month, but in all cases the possibility of water being held in ponds above should be considered.

Plate 10 shows the comparative fluctuations of the Passaic and Raritan, of about the same size, and of the Neshaminy and Batsto. This exhibit gives a good indication of the relative steadiness of the different classes of streams if we remember that, other things being equal, smaller water-sheds invariably fluctuate more than larger ones. These diagrams are all plotted in depths on the water-shed in 24 hours, so that we may compare the proportional flows per square mile of water-shed. A still more instructive exhibit is the diagram

of daily flow of the Passaic, covering 17 years, which is shown in Plate 8. The study of this diagram shows that practically every year but 1889 and 1890, or 15 years out of 17, shows quite an extended dry period, yet if we should take the average flow by months during these years, this dry period would be, to a considerable extent, hidden, since it does not always occur in the same months. It is for this reason that the average year which we have adopted, in accordance with the usual custom, and as an indication of the relative discharge of different sections, does not give a true conception of the real average of a period of years. This was the reason why we adopted for our ordinary dry year an actual year of rainfall, as shown by the records, and one which embodied an ordinary dry period, and this also explains the reason why our ordinary dry year exhibits a flow for 9 months about equal to what will be maintained on an average 9 months out of 12. In other words, the dry period exhibited by our ordinary dry year will be approximated to almost every year during some part of the year. The year which we have given as an average year has consequently but little economic value, and this is an illustration of the evil which has resulted from the practice of dealing too much with average rainfall, average flow and percentages in comparing different streams and estimating their capacity.

COMPUTED YIELD WITH STORAGE, VERIFIED BY GAUGINGS.

There is always a tendency to be optimistic in computing the amount of water available from a given water-shed. It may, at first sight, seem strange that there should be so wide a difference between what we have computed as the flow for the average year and the amount which can be collected and drawn upon at a uniform rate throughout the year during the driest period. The following table summarizes our estimates on the different classes of water-sheds, and will be found convenient for reference in this connection :

AVERAGE AND COLLECTIBLE FLOW-OFF OF STREAMS.

	AVERAGE FLOW-OFF.		ESTIMATED COLLECTIBLE.	
	Inches on water-shed.	Gallons daily per square mile.	Inches on water-shed.	Gallons daily per square mile.
Kittatinny Valley and Highlands........	24.41	1,162,000	14.00	666,094
Delaware River................................	24.75	1,180,000	14.00	666,094
Passaic River...................................	21.30	1,015,000	14.00	666,094
Red Sandstone Streams.....................	21.72	1,030,000	12.00	570,938
Trenton to Camden	20.66	985,000	12.00	570,938
Below Camden..................................	19.61	933,000	10.00	476,090
Coast Streams	21.88	1,040,000	12.00	570,938

Our remarks just previous as to the indications of an average year are pertinent in this connection also. While the average yield of different streams may be useful as a means of comparing different sections of the country, it is something which never occurs during any given year. On account of the tendency to estimate rather high as to the yield of a water-shed, to which we have already referred, there may be some who will regard the results which we have reached as too theoretical. No one who has followed us intelligently can fail to recognize, however, that these results are purely empirical, based on actual experience, but it may be well to further enforce our conclusions by referring directly to the actual gaugings. We have noted, during the progress of our studies, that the Sudbury, Croton and Passaic all show practically the same yield for a given rainfall. Turning now to the record of gaugings on the Sudbury, on page 48, we find that from June, 1882, to December, 1883, a period of 19 months, the total amount of water flowing off amounted to 14.33 inches, whereas a draught at a uniform rate equal to 14 inches per annum would require a total of 22.17 inches upon the water-shed. The difference of 7.84 inches, consequently, would have to be drawn from storage reservoirs, and these would at no time during this interval have been full, nor would they fill until the following March, or 22 months in all. This is a very long period for such reservoirs to be drawn down. If the draught had been reduced to

12 inches per annum they would have filled at the end of the twelfth month, which must be regarded as much more satisfactory.

Next, the Croton, from June, 1870, to January, 1871, a period of 8 months, shows a total flow of 3.98 inches, while a draught at the rate of 14 inches per annum would amount to 9.33 inches, leaving 5.35 inches to be drawn from storage, and the reservoirs drawn to this extent would not fill again until the following November, thus remaining drawn down a period of 17 months. Again, the same stream, from May, 1880, to June, 1881, would not more than comfortably fill its reservoirs at the end of the fourteenth month if drawn at the rate of 14 inches per annum. This is certainly strongly suggestive that during the still drier period in 1881 and 1882 we could not have collected more than 14 inches on the Croton water-shed.

Turning to the Passaic, from May, 1880, to January, 1881, a period of 9 months, the total flow-off was 5.54 inches, whereas a continuous draught at the rate of 14 inches per annum would have required 10.5 inches, so that 4.96 inches would have been drawn from storage. In this case, the reservoirs would have filled in March, the eleventh month after the draught began. At the end of November, 1881, the depletion of reservoirs would have amounted to 5.11 inches, but in this case it would have filled at the end of the eighth month. The only reason that the Passaic does not exhibit as small a dry-season flow as the Sudbury is, that its rainfall in no case falls so low. This may be, and we believe it is, due to the larger size of the water-shed, as we have previously pointed out that the most extreme droughts shown by our records are probably limited to about 100 square miles of area, and some part of a large water-shed is quite sure to receive some heavy showers during these protracted dry periods. It follows that we have no warrant for supposing that on a portion of the Passaic water-shed as small as that of the Sudbury the rainfall will not fall as low as the record upon that water-shed indicates, or as low as the dry period shown in the Philadelphia record during 1881 and 1882, on which we have based the dry-period flow shown by our tables. The same is true of the Tohickon, Neshaminy and Perkiomen. Our records there show a larger flow only because the rainfall is larger, and our studies indicate that not only is it likely at some time to fall as low as that of our driest period, but that in this case these streams would not yield as large a quantity of water as the Sudbury, since the evaporation is about one-tenth larger. Right here, it may be well to also call attention to the danger of reasoning that because these streams show a larger percentage of rainfall flowing off during the period of comparatively large rainfall covered by the gaugings, they will continue to show the same larger percentage in case the rainfall falls as low as that upon the Sudbury in 1882 and 1883. The real relation between rainfall and stream-flow is that shown by our formula (F equals 0.82 R minus 15.50), excepting as this amount might be augmented by draughts from ground-storage, thereby discounting, in a measure, the rainfall receipts of the following year. Our conclusions are, that all these streams obey the same law and that, given a water-shed no larger than the Sudbury, they will all be subject to as light a flow-off as that shown in 1882 and 1883, which we have cited above. For such water-sheds, we consider our estimates of yielding capacity to be the very highest that can safely be adopted. Indeed, we are disposed to recommend that in general a margin of 2 inches per annum under these estimates should be allowed where it can conveniently be done, as this will insure a more reliable and healthful supply. The waste which will result in the years of larger flow should not be regarded entirely as a loss. Some waste from storage reservoirs is, on the whole, desirable. Furthermore, floods may be regarded as nature's method of washing down and purifying the gathering-grounds. In many cases, very long periods of low reservoirs will result in an inconvenient increase in objectionable vegetable and animal micro-organisms.

SELECTION OF SOURCES OF SUPPLY.

In another chapter our exhibit of the water-supply of the State now in use shows that all but a comparatively insignificant amount is drawn from our streams. The results of chemical analysis leave little doubt that stream-waters are by far the best for domestic consumption as a rule. In selecting gathering-grounds for the supply of a city, it is of the first importance that the geological and topographical conditions should be favorable to purity. If otherwise, it will be almost impossible to maintain this supply in a satisfactory condition. The very best waters of the State are those from the Archæan Highlands. Not only is this true, but these streams are generally at a sufficient elevation to afford a gravity supply to our cities, thus saving the expense of pumping. Next to this, from a hygienic point of view, come the waters of the Tertiary pine plain in southern New Jersey. The character of these water-sheds is such that a most thorough natural filtration is in constant operation, and it is almost impossible for any considerable impurities to find their way from the water-sheds into the streams. Next in rank come the waters of the Kittatinny valley, then those of the red sandstone plain, and finally those of the clay and marl region. Indeed, the latter are practically the only streams which are ever objectionable in their natural state, and even here many of the smaller streams have sandy and gravelly water-sheds, and form fair gathering-grounds.

Next in importance in the selection of sources of supply, and only next because danger from this source may easily be remedied except in a few grave cases, comes the avoidance of sewage pollution incidental to populous water-sheds. This form of contamination should be avoided at any cost. No chemical analysis should be made the basis for continuing the use of a supply so polluted at any point near the source of pollution. Such waters may be used for a considerable period without causing any serious trouble, and yet, without a moment's warning, they may breed a disastrous contagion. The effects observed in this connection by the Massachusetts Board of Health at Lawrence, from the sewage of Lowell, 10 miles above, on the Merrimac, indicate that even a small amount of sewage may cause disease. In fact, the prevalence of typhoid at Lawrence appeared to be directly traced to a few individual cases occurring on one of the branches of the Merrimac, and from which the germs were communicated through the water-supply drawn from the river. This, however, is one of several similar cases. Even should a chemical and geological examination show no evidence of danger in a sewage-contaminated supply at a given date, this is no warrant for the conclusion that such water will continue to be safe for any length of time in the future. The extreme rapidity of increase of micro-organisms, which sometimes takes place in water under examination, is suggestive of these possibilities.

In this connection, it may be well to point out the proper place of chemical and microscopic analyses. There is no doubt that a considerable uncertainty exists even among the best authorities as to what confidence is to be placed on the results of these analyses, or, indeed, as to how they should be interpreted. Even the best and most careful conclusions reached seem to be occasionally contradicted by the facts. It is not difficult to discover and count the minute animal and vegetable organisms which exist in water, but as yet it is by no means certain always which of those are and which are not harmful. Unfortunately these uncertainties are sometimes made the basis for belittling or ignoring the warnings of such analyses, and frequently at the expense of large communities. The very reverse course would seem to be the wisest and most sensible one. Our ignorance in these matters should only breed the greater caution. In the absence of better data, we may perhaps go so far as to say that no source of supply which is repulsive to the natural instincts of intelligent persons should be tolerated. The senses of sight, smell and taste should always be exercised for our protection in the absence of other means, and only the most thorough and conclusive proof that such repulsive waters are not deleterious should be sufficient warrant for continuing their use.

In all cases a thorough physical examination should go hand-in-hand with chemical and microscopic tests. The latter may be valuable guides as to the character of the water and the proper methods of treatment to be adopted, but they can never take the place of the former. If there are visible sources of contamination, or even well-grounded suspicions that such exist, the failure of chemical analysis to indicate any danger should scarcely be accepted as conclusive as to the purity of the supply; but, on the other hand, if such analyses indicate danger, the source should be avoided, unless the cause of contamination can be discovered and removed.

Nothing can take the place of original purity of the source of supply. Filtration, aëration and all known methods of treatment, when applied to purify polluted waters, are at best uncertain in action when faithfully carried out, but doubly so under conditions which obtain in ordinary operations. Their legitimate province is not purification of contaminated waters, but to supplement nature when her work has not been effectual. Thus the waters of our red sandstone streams often carry a considerable amount of disagreeable sediment, although they are otherwise pure, soft and wholesome. Filtration and settlement will do much to improve such waters, and indeed will often render them thoroughly desirable. This sediment has also sometimes been successfully precipitated by the use of alum, but this treatment also is only desirable when carefully regulated. Again, many streams do not have sufficient fall, and flow in smooth, quiet currents through their channels, so that they do not obtain the thorough aëration of our Highland streams, which boil and tumble over their stony beds. There is evidence that such waters may be substantially improved by artificial aëration.

Apart from the above considerations, which are mainly sanitary, hardness sometimes renders waters unfit for domestic use, and some waters may even be so extremely hard as to be unhealthful, but as a rule this is not the case with New Jersey stream-waters. Some waters also have a decidedly corrosive action on steam-boilers and cooking utensils. Some of the southern New Jersey waters are subject to criticism on this ground. If the waters are otherwise in all respects desirable, however, it is probable that means could be found to counteract this action. It is a matter which should have consideration in the choice of a source of water-supply.

In almost any section of the State some small streams may be found issuing from swamps which have a disagreeable taste and odor, and are to be avoided. This peculiarity is one easily detected, however, and such streams are, moreover, quite rare.

CHEMICAL ANALYSES.

We have had a few analyses made for this report, and to these we have added some others previously made by the Survey and some from other sources. The purpose is to give a general idea of the chemical composition of the various waters of the State in their natural condition, and no attempt has been made to make such studies as would indicate the presence of sewage pollution or other artificial contamination. The conditions of such pollution change so rapidly that such studies could not be of permanent value as an aid to the selection of a proper source of supply. We have added, for purposes of comparison, a few analyses of waters in the neighboring States. We have intended that this exhibit should, on the whole, form a standard of purity for New Jersey stream-waters better than any arbitrary standard which may be set up. We would especially condemn the use in this State of any standards which have been set up as applicable to less favored portions of the United States, as a considerably higher standard may be possible here. We have quoted, in the third table, however, the standard given by Dr. Albert R. Leeds, of Hoboken, the well-known authority on this subject, which may be found convenient for general reference.

ANALYSES OF STREAM-WATERS MADE FOR THIS REPORT, BY PROF. ALBERT H. CHESTER.

Parts in 100,000.

	Pequest at Belvidere, November, 1894.	Musconetcong at Bloomsbury, November, 1894.	Raritan at Finderne, October, 1894.	Millstone near mouth, October, 1894.	Crosswicks at Crosswicks, July, 1894.	Back creek at Lowry's pond, July, 1894.	Great Egg Harbor at Mays Landing, September, 1894.	Maurice river at Millville, September, 1894.
Total solids	16.94	9.17	10.81	8.05	10.40	6.71	4.31	3.81
Inorganic (salts)	13.83	6.13	7.47	5.20	4.36	4.10	2.06	2.04
Volatile organic	3.11	3.04	3.34	2.85	6.04	2.61	2.25	1.77
Silica	1.27	1.06	1.65	1.10	.94	.29	.74	.53
Oxides of iron and aluminium	.17	.19	.05	.10	.39	.15	.15	.17
Calcium oxide	4.24	1.70	1.72	.94	1.48	.45	.12	.15
Magnesium oxide	2.03	.86	.72	.34	.02	.29	.02	.10
Sulphuric trioxide (SO_3)	.96	.39	.45	.81	.14	.27	.17	.15
Chlorine	.21	.21	.19	.38	.08	.17	.03	.08
Sodium chloride	....	....	.33	.64	....	....	....	....
Hardness	12.12	6.61	6.45	4.60	4.10	2.45	1.23	1.65
Reaction	alk.	alk.	alk.	alk.	acid.	acid.	acid.	acid.

These samples all taken directly from the streams.

ANALYSES OF STREAM-WATERS FROM PREVIOUS REPORTS OF THIS SURVEY.

Parts in 100,000.

	Hackettstown, from springs, August, 1876.*	Passaic above Two Bridges, July, 1876.	Passaic at Hanover, July, 1876.	Ramapo at Pompton lake, August, 1876.	Wanaque near Pompton, August, 1876.	Pequannock near Pompton, August, 1876.	Rockaway below Dover, August, 1876.	Rockaway, Lower Longwood, August, 1876.	Elizabeth river, August, 1876.*	Rahway, Orange reservoir, December, 1884.	Rahway river, Rahway, August, 1876.*	Alexsocken creek, Lambertville, October, 1879.	Lawrence's brook, New Brunswick, 1876.*	Rancocas, Mt. Holly, 1876.*
Total solids	2.15	7.72	7.22	4.50	4.00	6.00	8.58	6.44	13.44	7.00	17.44	14.60	2.75	4.05
Inorganic	....	5.72	5.01	3.50	2.86	4.58	7.87	....	10.30	5.48	15.44	9.87	1.43	3.58
Volatile organic	....	2.00	2.21	1.00	1.14	1.42	.71	....	3.14	1.52	2.00	4.73	1.32	.47
Lime	.56	1.69	....	1.12	.88	1.12	1.79	1.29	2 88	.13	4.83	....	.37	.29
Magnesia	.31	1.24	....	.72	.62	.82	1.23	.93	.93	....	1.24	....	.27	.41
Sulphuric acid	.59	.34	.98	.39	.39	.39	.98	.20	1.08	.36	3.19	....	.39	.39
Chlorine	.14	.28	.29	.17	.21	.21	.22	.15	.57	.60	.43	.26	.13	.21
Ammonia, free	.001	.010	.013	.008	.006	.003	009	.002	.013	Tr.	.004	.080	....	.003
Ammonia, albuminoid	.011	.012	.012	.022	.016	.012	.012	.013	.031	.017	.014	.113	.016	.013

* These samples all taken from hydrants, all others directly from the streams.

ANALYSES OF PURE STREAM-WATERS FROM OTHER SOURCES.

Parts in 100,000.

	Dr. A. R. Leeds' standard for United States.	Merrimac at Lowell, 1889–90.	Connecticut, Turner's Falls, 1889.	Sudbury, Farm pond, 1890.	Lake Cochituate, 1890.	Croton, July, 1881.	Delaware at Byram, 1885.	Delaware at Water Gap, 1885.	Perkiomen, Green Lane, 1885.	Passaic above Two Bridges, September, 1883.	Pompton above Two Bridges, September, 1883.	Crosswicks at Bordentown, May, 1892.
Number of samples	....	19	1	19	19	1	44	13	13	1	1	1
Total solids	20.00	3.57	4.80	5.23	4.74	9.00	6.88	4.91	9.88	9.80	6.50	5.71
Inorganic	....	2.03	3.20	3.85	3.71	7.00	....	....	....	....	....	....
Volatile organic	....	1.54	1.60	1.38	1.03	2.00	....	....	....	....	....	....
Chlorine	1.000	.14	....	.67	.49	.067	.266	.227	.39	.50	.30	.30
Ammonia, free	.012	.0018	.0024	.0022	.0020	.0020	.0028	.0025	.0043	.0	.0005	.002
Ammonia, albuminoid	.028	.0142	.0156	.0208	.0193	.0150	.0099	.0105	.015	.013	.013	.005
Nitrates	.500	.0097	.0050	.0072	.0190	.0018	.2543	.2393	.36	.20	.11	.0
Nitrites	.001	.0001	.0001	.0001	.0003	Tr.	Tr.	Tr.	.0002	.0	.0	.0
Hardness	....	1.4	....	2.2	2.4	....	....	....	....	4.00	3.60	3.60
Oxygen required	.500	....	....	....	....	.216	.315	.289	.293	.22	.31	.26

NOTES.—Dr. Albert R. Leeds gives the above general standard of purity for river-waters of the United States (maximum allowable impurity) in Report of Philadelphia Water Department for 1883.

Merrimac, Sudbury, Connecticut, Cochituate from Report of State Board of Health of Massachusetts, 1890.

Croton, Report of National Board of Health, 1882.

Delaware, Perkiomen and later Schuylkill and Lower Delaware analyses from the report of Dr. Albert R. Leeds to the Chief Engineer of Philadelphia Water Department.

Passaic and Pompton, Dr. Leeds, Report of State Commissioners of Water-Supply, March, 1884.

Crosswicks, Prof. H. B. Cornwall, from hydrant.

SOME ANALYSES OF WATER LARGELY POLLUTED COMPARED WITH THE SAME STREAMS UNPOLLUTED.

Parts per 100,000.

	Total solids.	Volatile organic matter.	AMMONIA.		Chlorine.	Nitrates.	Nitrites.	Oxygen consumed.
			Free.	Albuminoid.				
August 31st, 1876.								
Passaic, Jersey City Intake, high tide..	27.17	6.29	.0133	.0215	9.152	......	....	......
Passaic, Jersey City Intake, low tide..	11.15	3.43	.0100	.0190	1.001	......	....	......
Average	19.16	4.86	.0116	.0202	5.076	......	....	......
August 21st, 1894.								
Passaic, Jersey City Intake, high tide..	23.75	5.75	.078	.064	7.45	......	....	......
Passaic, Jersey City Intake, low tide...	14.50	5.00	.056	.062	2.48	......	....	......
Average..............................	19.12	5.37	.067	.063	4.97	......	....	......
September, 1883.								
Passaic, unpolluted, at Two Bridges...	8.15	....	.0003	.013	.400	......	....	......
Delaware at Frankford, 1883-5, 17 samples..................................	8.30	....	.0039	.0149	.329	.328	Tr.	.308
Delaware at Byram, 1883-5, 44 samples..	6.88	....	.0028	.0099	.266	.254	Tr.	.315
Delaware, unpolluted, at Water Gap, 1883-5, 13 samples....................	4.91	....	.0025	.0105	.227	.239	Tr.	.289
Schuylkill, Spring Garden Pumping Station, 1883-5, 59 samples—								
Average..............................	11.95	....	.008	.015	.523	.39	.0006	.22
Maximum..............................	19.00	....	.019	.031	1.00	.80	.01	.96
Minimum..............................	6.00	....	.0005	.0085	.175	.09	....	.08

NOTE.—The Passaic, in 1876, from Geological Survey Report, 1876; for 1894, from presentment of Hudson county grand jury, and at Two Bridges, 1883, the average of the two analyses from Report of Commissioners of State Water-Supply previously given, this water being unpolluted. Delaware and Schuylkill from Dr. Leeds' report to Water-Supply Department of Philadelphia.

In the first tables of analyses, we have included only waters which are not seriously polluted, and, excepting possibly the Elizabeth and Rahway rivers, they may be considered pure stream-waters. The last table gives waters known to be seriously polluted, and is given here for ready comparison, although it will be more fully referred to a little later when we consider the subject of stream pollution.

The first column, showing total solids, is not of great practical importance, although Dr. Leeds thinks that these should not exceed 20 parts in 100,000. The volatile organic matter represents the portion of the solid matter which disappears on combustion of the total solids. It is a general measure of the amount of organic matter, but not all of this is necessarily deleterious. More importance is to be placed upon the showing of ammonia and chlorine.

Free ammonia.—This is, usually, mainly a product of the decomposition of organic matter: A small amount is normal and appears even in rain-water, and this is partly drawn from the air. Any considerable amount of free ammonia is a cause to suspect contamination. By Dr. Leeds' standard, it should not exceed 0.012 parts in 100,000. It will be seen that the Upper Passaic, at Hanover, and Elizabeth river exceed this in the analysis. We have not recommended either of these sources after a physical examination, but paper mills may be the cause of the excess on the Upper Passaic. In our table of polluted waters, it will be seen that the Passaic, at Belleville, shows 0.067 parts of free ammonia in 1894. None of the analyses of the Delaware approach the limit, but the Schuylkill is often much in excess.

Albuminoid ammonia.—This represents animal and vegetable matters present in the waters and in process of decomposition, by which process free ammonia is produced, consequently it is more to be dreaded than the latter, as at certain stages of decomposition such matter becomes very dangerous to health. Dr. Leeds' limit is 0.028, which is exceeded only in the case of Elizabeth river and some streams which we know to be seriously polluted—the Passaic, at Belleville, showing 0.063 and the Schuylkill sometimes as high as 0.031.

Chlorine.—This is not only an accompaniment of sewage pollution, but is a measure of the amount of such pollution, although not always of the danger to be apprehended therefrom. A certain amount is normal, and in order to make the determination of chlorine of the greatest value it is necessary that this normal amount be determined. This has been thoroughly done in Massachusetts by the State Board of Health, and is shown by a map in the report of 1890. For the western half of that State, it does not exceed 0.10, and eastward, to within about 25 miles of the ocean, increases slowly to 0.20, but nearing the ocean, it increases rapidly to about 0.65, which is even exceeded in a few cases. Dr. Leeds gives the maximum allowable at one part in 100,000. In general, our streams of known purity do not exceed 0.30, and there is no increase observable in southern New Jersey stream-waters nearer the ocean. In fact, all southern New Jersey waters seem very low in chlorine. Studying the amount of chlorine shown and keeping in mind what we know of the principal sources of pollution and the relative populousness of the water-sheds, this appears to indicate closely the relative purity of the streams of the State.

Of the polluted waters, the Passaic shows about 5 parts in 100,000 at Belleville. The very large amount shown at high tide is undoubtedly due to sea-waters, but even at low tide it is seen to be much more than is admissible. It is also interesting to observe that the unpolluted Passaic at Two Bridges shows only 0.4 part of chlorine. It may be well to state here that the comparison of these three sets of analyses of the Passaic seems to be perfectly fair, as they are all at about the same time of the year, and all made during a low stage of the river. The figures given at Two Bridges are the average of the Pompton and the Upper Passaic, two streams of about equal size, which meet here to form the Passaic. The Schuylkill shows an average of 0.523, and a maximum of one part chlorine, and we may remark, with respect to the Schuylkill, that it is fairest to compare the maximum figures with the figures for the Passaic, which are probably about a maximum. It is interesting also to note the steady increase in the amount of chlorine in the waters of the Delaware as we descend the stream.

We cannot do better, in this connection, than to quote the remarks of Dr. Leeds as to chlorine in the Philadelphia report:

> "Every increment of sewage to the waters of a flowing stream is represented by a permanent increase in the percentage of chlorine. On the other hand, such increments may not be represented by a permanent increase in the organic constituents, the latter being represented in the analyses by the ammonia, nitrogen acids and oxidizable organic substances. Instead of an increase, the factors representing the organic constituents may actually diminish in amount. They increase when the processes of natural oxidization in a flowing stream are inadequate to cope with the burden of sewage, whilst they diminish (even though the absolute quantity of sewage added is very large) when the reverse is the case. But in either event, the percentage of chlorine goes on steadily increasing." (Report of the Chief Engineer of the Philadelphia Water Department, 1885, page 386.)

It is apparent, therefore, that the presence of chlorine in more than normal amount is sufficient cause for the rejection of a water in case the source of pollution cannot be removed, if we do not care to take the chances of trusting to oxidization and purification of streams thus polluted.

Nitrates and nitrites.—Pollution by sewage being practically the addition of nitrogen compounds to the water, the process of purification of this water consists of the oxidization of these compounds, and when this process is completed they become nitrates. Nitrites indicate that this work of purification is in progress but is not complete, consequently their presence is a more serious matter than that of nitrates.

Sulphuric acid.—This is not particularly injurious, but its presence is a matter of interest to the users of steam-boilers if it is in any considerable amount.

Lime and magnesia.—If these are present to an amount exceeding 4 parts in 100,000 the water is hard, but if less than this it is considered a soft water. In some instances our analyses show the hardness of the waters. The only cases among the pure stream-waters where the hardness seems to be appreciable are the Pequest and Rahway. The Highland streams are all remarkably soft waters, and those of southern New Jersey are apparently as soft as rain-water.

Those who wish to study the subject of chemical analyses of stream-waters and the results of some of the latest and best work therein, cannot do better than consult the labors of Prof. T. M. Drown, in the Reports of the State Board of Health of Massachusetts, to which we acknowledge indebtedness.

STREAM POLLUTION.

While most of our Highland streams, those of the Kittatinny valley, the Delaware above Trenton and the streams of the Tertiary plain, are as yet unpolluted, it is evident that many of them are now threatened with sewage pollution, and they will not long remain in their present purity unless the small towns along their courses are restrained from using them as an outlet for sewage. In the Highlands, we have the following places which are at present most to be feared: On the Ramapo, Suffern and Tuxedo Park, in New York.

The latter already has a small sewer emptying into the stream. On the Pequannock, Bloomingdale and Butler together form, practically, the only threatening center. On the Rockaway, Boonton may be disregarded, as any supply from that stream should be, and readily could be, drawn off above this place, but above this we have Rockaway village and Dover, the latter of which, at least, is contemplating sewerage. Port Oram and Hibernia are both mining towns and are not increasing in population. While they should not be ignored, they do not threaten serious pollution. On the Upper Passaic and Whippany, we have Morristown, Madison, Chatham and Summit, all of which are growing quite rapidly, and these, with Boonton, threaten the Passaic above Paterson. On the Musconetcong, Hackettstown has a water-supply, and it is probable that some trouble will be caused from sewage in the future. Kittatinny valley streams are threatened by Washington, Belvidere and Newton, but not to any serious extent at present.

While at present the Delaware above Trenton appears to be a wholesome and safe source of supply, the fact must not be disregarded that on the portion of the river below Easton and on the Lehigh there is a large city and town population supplied with water, and while not many of these places are at present sewered, there is little doubt that they will be in the near future. The following table gives the population and the amount of water supplied to these towns. Although we do not wish to be understood as measuring the danger from pollution directly by the amount of such pollution, the proportion of sewage to the whole flow of a stream is nevertheless strongly suggestive and helpful, especially if we remember that this dry-season flow does not increase, while the amount of sewage increases, as a rule, more rapidly than the increase of population, which, for the towns we are considering, is about 30 per cent. in each decade. The average flow at Trenton during the driest month is 880,000,000 gallons daily, so that the proportion of sewage of these towns, measured by the water-supply of 1890, to the whole flow of the Delaware during the driest month, is about one part in 90. It is apparent, from the table, that the worst pollution on the Delaware above Trenton is at the mouth of the Lehigh. On account of the numerous rapids, conditions are favorable to oxidization and purification, and the river must gradually improve below this point, as the additional amount of sewage received is insignificant. Above Easton, the Delaware is, and promises to be for some years, all that can be desired for purity. The population of the water-shed above Lambertville is 59 per square mile and above the Water Gap it is but 32 per square mile. The Lehigh alone has a population of 120 per square mile.

TOWNS ON THE DELAWARE ABOVE TRENTON WHICH THREATEN POLLUTION.

	Population, 1890.	Water-Supply. Gallons Daily, 1890.*
Lambertville, N. J	4,142	500,000
Hackettstown, N. J	2,417	100,000
Washington, N. J	2,834	100,000
Phillipsburg, N. J	8,644	300,000
Easton, Pa.	14,481	1,500,000
South Easton, Pa	5,616	40,000
Bethlehem, Pa	6,762	650,000
South Bethlehem, Pa	10,302	700,000
West Bethlehem, Pa	2,759	
Allentown, Pa	25,228	2,400,000
Catasauqua, Pa	3,704	50,000
Slatington, Pa	2,716	324,000
Lehighton, Pa	2,959	200,000 (est.)
Mauch Chunk and East Mauch Chunk, Pa	6,873	490,000
Hazelton (part of), Pa	8,000	350,000
Total, Lower Delaware and Lehigh	107,437	7,704,000
Belvidere, N. J	1,768	200,000
Stroudsburgh and East Stroudsburgh, Pa	4,238	6,000
Milford, Pa	793	60,000 (est.)
Port Jervis, N. Y	9,327	1,200,000
Honesdale, Pa	2,816	100,000
Deposit, N. Y	1,530	300,000
Delhi, N. Y	1,564	100,000 (est.)
Total, Delaware above Easton	22,036	1,966,000
Total, Delaware above Trenton	129,473	9,670,000

On the Delaware below Trenton conditions are much more serious. Trenton is now being sewered, and measuring the sewage by the average amount of water supplied during 1893 it will amount to 5,610,000 gallons daily, and the population is increasing at the rate of 60 per cent. every ten years. The flow of the river during the driest month at this place is 880,000,000 gallons daily, so that, disregarding the sewage received above, which may be considered as all oxidized at this point, the Trenton sewage will amount to 1 part in 157, or at the very lowest stage of the river 1 part in 120.

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* From the Manual of American Water-Works.

Including all towns from Trenton down to the mouth of the Schuylkill, and those on the Schuylkill up as far as Norristown, we find a city population of 1,240,000 by the census of 1890, which is increasing at the rate of over 25 per cent. in 10 years, and the volume of sewage, measured by the water-supply in 1893, is not less than 200,000,000 gallons daily, while the average flow of the river during the driest month is not over 1,283,000,000 gallons daily. The sewage is therefore about 1 part in 6. It is apparent that the condition of the water above Philadelphia, in the Delaware, will be much worse during the flood than it is during the ebb tide. It would also seem that in a deep channel such as this, with a smooth, quiet current, the opportunities for oxidization must be limited. The preservation of this lower portion of the Delaware in a sufficiently pure condition to serve as a safe source of water-supply would appear to be hopeless. As in the case of the Lower Passaic, little more can be hoped for than to reduce the pollution below the point where it will render the stream a nuisance to the surrounding district. It should be remarked that the condition of the Delaware is now much worse than it was 10 years ago, when the analyses were made which we quote in our table.

The streams of the red sandstone plain northeast of the Raritan are also for the most part becoming rapidly contaminated. The worst case is that of the Passaic below Paterson. In our table of analyses of polluted streams we gave results for 1876 and 1894, both in August, at Belleville; and also for the unpolluted stream at Two Bridges early in September, 1883. As these were all times of low water the comparison is a fair one, and taking the average for high and low tide in 1876 and in 1894 the effect of increasing pollution is apparent. The total solids appear to be about the same, but the latter analyses show a larger proportion of volatile organic matter. Even at low tide the total solids exceed those at Two Bridges by 50 per cent. Between the two dates the river at Belleville shows an enormous increase in both free and albuminoid ammonia. The chlorine appears to be about the same, but it is probable that this indicates a larger proportion of unoxidized sewage only, and that the river has reached its limit of capacity to purify itself. It is quite evident that the danger of using this water is now many times greater than when it was first condemned in the reports of the Survey, in 1876. It is interesting, in this connection, to show the population and extent of the district from which this pollution comes. This is done in the following table, which shows further the percentage of increase in population and the total volume of sewage as measured by the figures of water supplied during the last year:

SOURCES OF POLLUTION OF THE LOWER PASSAIC.

Town.	Area in Square Miles.	Population, 1890.	Per cent. Increase, 1880–1890.	Water Supplied—Million Gallons Daily.
Newark	21.00	181,830	33	21,100,000
East Orange	3.90	13,282	59	1,500,000
Bloomfield	6.73	7,708	35	
Orange	2.14	18,844	43	1,500,000
Montclair	6.18	8,656	69	200,000
Belleville	2.93	3,487	16	....
Franklin	3.49	2,007	25	....
Passaic	3.24	13,028	99	1,400,000
Acquackanonk	11.34	2,562	47	....
Paterson	8.47	73,347	54	13,000,000
Harrison	1.31	8,338	......	600,000
Kearny	10.28	7,064	......	196,500
	81.01	340,153	42	39,496,500

It will be seen that this district has an average population of 4,200 per square mile, and that it covers an extent of 81 square miles, mostly between Passaic river and the crest of Orange mountain. It is not only nearly all sewered, but the slopes are steep and every facility is offered for surface drainage to the streams. As the average flow of the river during the driest month is 120,500,000 gallons daily, the above sewage represents one-third of the whole flow, which is truly an alarming condition. Even if we exclude Newark entirely, it will be seen that pollution amounts to about one part in six. Furthermore, it often happens in an extremely dry period that the whole flow of the river is retained in the ponds above Paterson for a period of thirty-six hours, which greatly aggravates the conditions in the lower channel. It will be seen that the conditions are quite bad enough to account for the results indicated by the analysis of 1894, and that any attempt to preserve the purity of the Passaic below the falls in a sufficient measure to render it a safe source of water-supply will be a vain one. Indeed, it will be found necessary in the near future to conduct as much as possible of this sewage to Newark bay,

THE PASSAIC BELOW PASSAIC BRIDGE.

thus relieving the river channel, as a measure of health to this populous bordering district.

It may be laid down as a rule that, especially in the red sandstone district, but generally everywhere in the State, the preservation of any water-supply drawn from the tidal portion of our rivers will be an impossibility.

All of the red sandstone streams are in more or less danger of contamination, but the streams of the Tertiary plain are not only naturally protected from serious pollution, but there are very few centers of population above the head of tide to be guarded against.

While it may not be wise to attempt to redeem these wholly-polluted streams, there is abundant necessity that steps should be taken to guard the choice gathering-grounds of our Highlands. These are pre-eminently the sources to which we must look for the future water-supply of the State, and the time when they will all be needed is apparently not half a century distant. Indeed, they are already coming rapidly into use, and to allow them to be contaminated from the threatening sources which we have called attention to will be unpardonably short-sighted.

VALUE OF ELEVATION OF THE SOURCES OF SUPPLY.

If the source of a water-supply lies high enough to deliver the water to a city by gravity a very material saving is effected, amounting to the cost of pumping. This varies with the duty of the pumps, the cost of coal and with the amount pumped, being less for large than for small plants. The city of Philadelphia pumps all its large supply and keeps careful records of the cost of operation, which will give us a good idea of the average cost for recent years for large plants. From 1887 to 1893, the average cost of pumping by steam-power amounted to $3.89 for each million gallons raised 100 feet. For greater lifts the cost will be proportional. This cost includes labor, fuel, supplies and repairs, but nothing for depreciation, interest on cost of plant or taxes. The average quantity raised during these seven years ranges from 60,000,000 to 150,000,000 gallons daily. A portion of this supply was also pumped by water-power, and for this the average cost was $1.21 for 1,000,000 gallons raised 100 feet. The total cost of pumping for 1893 was about $356,000. Jersey City, in 1891, expended $149,465.48 for wages, fuel, supplies and repairs in pumping the supply of that city from the Passaic. Apparently the cost here was not less than $9 per 1,000,000 gallons raised 100 feet, although we have not the exact figures. The amount pumped was about 21,000,000 gallons daily. During five years, or from 1889 to 1893, the average cost of pumping at the New Brunswick water works has been $4.46 for 1,000,000 gallons raised 100 feet, 69 per cent. of the water being pumped by water-power and 31 per cent. by steam-power. The quantity pumped ranged from an average of 1,250,000 to 1,500,000 gallons daily for each year.

In general, it is probably safe to assume that the cost of operation of a steam pumping plant will not be less than $5.50 for each 1,000,000 gallons raised 100 feet with good modern machinery and at the average cost of coal during the last five years. The actual cost of pumping throughout the State is very considerably in excess of this.

We may assume that the water will be required to be raised a height of 200 feet, including friction in the mains. It will therefore cost for a pumped supply about $11 for each 1,000,000 gallons consumed, or $4,020 per annum for each 1,000,000 gallons daily. Other things being equal, this will be the value of a supply by gravity over one which must be pumped.

HIGHLAND WATER-SHEDS THE STATE GATHERING-GROUNDS.

The results of our studies will be seen to be that the Highland water-sheds are the best in the State in respect to ease of collection, both because of facilities for storage and a smaller amount required for a given yield; in geological and topographical features favorable to purity; in scantiness of population, which in general shows a tendency to decrease; in elevation, sufficient to afford a gravity delivery, and in actual softness and purity, as shown by the results of the chemical analyses. We cannot too strongly enforce the remarkable excellence of these gathering-grounds and their peculiarly favorable location close to the great urban population of our northeastern counties. In addition to the advantages already enumerated, these water-sheds lie at sufficient elevation to furnish water to the remotest town of the State without pumping. The following table shows the water-sheds included in this district, the elevation at which the waters may be drawn off, their area in square miles and their supplying capacity with storage:

HIGHLAND WATER-SHEDS ABOVE 300 FEET ELEVATION.

Streams.	Elevation.	Drainage. Square Miles.	Supplying Capacity. Gallons Daily.
Ramapo	300	134.5	89,600,000
Wanaque	300	87	58,000,000
Pequannock	370	82	54,700,000
Rockaway	480	118	78,700,000
Upper Passaic	300	9	6,000,000
Raritan, North Branch	400	17	11,300,000
Lamington	600	31.4	21,000,000
Rockaway creek	400	12.5	8,300,000
Raritan, South Branch	500	55.5	37,000,000
Musconetcong	400	122.4	81,600,000
	......	669.3	446,200,000

In this table we have given the proper elevation for a good practical development of the whole water-shed in each case, being nowhere less than 300 feet and higher where no considerable loss in the area of the gathering-ground would result by such increase. All of the Passaic headwaters may be drawn off at 300 feet or higher, and those of the Raritan and the Musconetcong at 400 feet or higher. By a proper system of development, these available gathering-grounds could be made to supply every city in the State by gravity with all the water needed during the next half century, if we estimate the future increase in demand to be proportional to the increase of population during the past twenty years.

The land included in this area is, as a rule, more available for forest culture than for agriculture. The percentage of cultivated land is small, and a large portion can never be tilled. In fact, there is no tendency to increase the amount of cleared land, and in the past a considerable amount of such land has been allowed to again grow up in forest. We have seen that the streams are at present entirely unpolluted, but are beginning to be threatened.

When the above supply shall be exceeded, our cities will be compelled to look to the Delaware, but the ease with which the Highland district may be guarded from pollution, as compared with the Delaware, which lies in three States, is very marked.

OWNERSHIP OR CONTROL OF SMALL WATER-SHEDS.

We have already called attention to cases in which it may be desirable for communities to own outright, or otherwise thoroughly control, the gathering-grounds of their water-supply. The large number of communities in the northeastern part of the State, and in general those upon the red sandstone and clay and marl regions, will find this course often not only the most secure, but the most economical. The average distance from the populous northeastern section to the unpolluted and comparatively unthreatened water-sheds of the Highlands may be taken to be 20 miles. Even if they go to this distance, they have at present no assurance that their supplies will remain uncontaminated. Let us assume a community wishing to provide for a future population of 20,000. We have seen that, with storage, streams of the red sandstone district and southern New Jersey will easily yield 12 inches annually, or 570,928 gallons daily for each square mile of water-shed. The average demand of such a community as we have assumed is at present 60 gallons per capita daily, and this would appear to be sufficient for ordinary use in inland towns, so one square mile will furnish water to 9,500 persons. In other words, for each 1,000 of population 67.4 acres will be necessary, and our community of 20,000 population would require 1,348 acres to be purchased to secure the entire control of their gathering-grounds. If we assume this to cost $100 per acre, the total would be $134,800. To bring this water from a distance not less than 12-inch mains would be needed, which would cost, exclusive of the right of way, about $6,500 per mile, or $130,000 for our assumed distance of 20 miles. When we come to add to this the cost of right of way, it will be seen that a saving of 20 miles in distance will very much more than pay for the purchase of the gathering-grounds near at hand. It would not even always be necessary to purchase the entire area. The end would be accomplished by securing the portion along the streams and keeping the same in forest or grass. In this way not more than one-half the above cost would be necessary, or the same outlay might be applied to control a larger supply to allow for future increase.

In some cases such areas might be utilized for parks, or there might even be an income derived from them by leasing as game preserves, or for forest culture or other uses not inconsistent with the preservation of purity of the supply. There are many areas within the red sandstone region which would, if treated in this way, yield a highly-desirable supply of water entirely free from the characteristic red mud, which is largely the result of the exposure of bare or cultivated surfaces. There is no other plan of obtaining a supply which offers the same security as this from future pollution. Many small, gravelly water-sheds in the clay and marl district are equally well adapted to such treatment, and it offers a solution of a problem which for our smaller communities threatens to become a perplexing one as population increases, and they are forced to abandon their near-by sources of supply.

PUBLIC WATER-SUPPLY SYSTEMS OF NEW JERSEY CLASSIFIED BY SOURCES.

Northern Streams by Gravity.

TOWN.	STREAM.	Population of town, 1890.	Daily consumption, 1893—gallons.	Treatment of water	REMARKS.
Newark	Pequannock	181,830	20,100,000	None.	
Orange	Rahway	18,844	1,650,000	None.	
Morristown	Springs	8,156	350,000	Strained.	
Dover	"	4,000	60,000	None.	
State Insane Asylum, Morris Plains	"	1,350	250,000	Filtered.	
Lambertville	Swan's creek	4,142	200,000	None.	
Washington	Brass Castle creek	2,834	*100,000	None.	
Hackettstown	Springs	2,417	*100,000	None.	
Bound Brook	Middle brook	1,462	100,000	None.	
Pennington	Springs	700	15,000	....	
Little York	"	100	5,000	....	
Total Gravity Supply		225,835	22,930,000		

Northern Streams by Pumping.

Hoboken	Hackensack	43,648	....	....	
West Hoboken	"	11,665	....	....	Combined.
Union town	"	10,643	....	....	Supply by Hackensack Water Co.,
Hackensack	"	6,004	....	....	
Englewood	"	4,785	....	....	Re-organized.
Rutherford	"	2,293	....	....	
North Bergen	"	5,715	....	....	
Guttenberg	"	1,947	....	....	
Weehawken	"	1,943	....	....	
Ridgefield	"	5,477	....	....	
		94,120	6,900,000	Aerated.	
Jersey City	Passaic	163,003	....	....	
Bayonne	"	19,033	....	....	
Harrison	"	8,338	....	....	
Kearny	"	7,064	....	....	
		197,438	23,000,000	None.	Unsatisfactory.
Paterson	"	78,347	13,000,000	None.	
East Orange	Springs	13,282	1,500,000	None.	
Bloomfield	"	7,708			
Passaic	"	13,028	1,400,000	None.	
Rahway	Rahway	7,105	1,000,000	Filtered.	
Somerville	Raritan	3,861	800,000	Filtered.	
Raritan	"	2,556			
Flemington	"	*2,000	100,000	None.	
State Insane Asylum, Trenton	Springs	1,200	100,000	None.	
Nutley	"	*700	35,000	None.	
Blairstown	Blair's creek	500	10,000	None.	
Total Pumped from Northern Streams		421,845	47,845,000		

* Estimated.

PUBLIC WATER-SUPPLY SYSTEMS OF NEW JERSEY CLASSIFIED BY SOURCES—Con.

Delaware River by Pumping.

TOWN.	STREAM.	Population of town, 1890.	Daily consumption, 1893—gallons.	Treatment of water.	REMARKS.
Camden	Delaware	58,313	10,000,000	None.	Unsatisfactory.
Trenton	"	57,458	5,610,464	None.	
Phillipsburg	"	8,644	300,000	Filtered.	Infiltration wells.
Burlington	"	7,264	400,000	None.	
Bordentown	"	4,232	*250,000	Filtered.	Unsatisfactory.
Belvidere	"	1,768	200,000	None.	
Beverly	"	1,957	300,000	None.	
Riverton and Palmyra	"	3,000	150,000	Filtered.	Largely from infiltration well.
Total from Delaware		142,636	17,210,464		

Southern Streams by Pumping.

New Brunswick	Lawrence's brook	18,603	1,521,097	None.	
Perth Amboy	Tennent's brook	9,512	1,100,000	None.	16,550 gallons daily to South Amboy.
South Amboy	" "	4,330			
Bridgeton	East lake	11,424	500,000	None.	Also wells.
Millville	Maurice river	10,002	500,000	None.	
Long Branch	Whale Pond brook,	7,231	1,000,000	Filtered.	Monmouth Beach also.
Mount Holly	Rancocas	5,376	225,000	None.	
Woodbury	Mantua creek	3,911	225,500	None.	
Moorestown	Pensauken	2,500	135,000	None.	Unsatisfactory.
Haddonfield	Cooper's creek	2,502	75,000	None.	
Lakewood	Metedeconk	2,000	280,000	Filtered.	
Merchantville	Springs	1,225	150,000	None.	
State Reform School	"	500	40,000	None.	
Wenonah	"	500	25,000	None.	
Total from Southern Streams		79,616	5,776,597		

From Open Wells.

Montclair	....	8,656	200,000	....	
Red Bank	....	4,145	150,000	....	Also tube wells.
Summit	....	3,502	450,000	....	Also a tube well. 125,000 gallons daily to South Orange.
South Orange	....	3,106			
Cape May City	....	2,136	500,000	....	
Madison	....	*2,000	150,000	....	
Princeton	....	3,422	75,000	....	
Lawrenceville School	....	....	15,000	....	
		26,967	1,540,000		

* Estimated.

PUBLIC WATER-SUPPLY SYSTEMS OF NEW JERSEY CLASSIFIED BY SOURCES—Con.

From Tube Wells.

TOWN.	STREAM.	Population of town, 1890.	Daily consumption, 1893—gallons.	Treatment of water.	REMARKS.
Plainfield		11,267			Wells at Netherwood, part of supply to Elizabeth.
Westfield		*2,000			
Cranford		*1,500			
		14,767	1,603,000	None.	
Gloucester		6,564	1,000,000	None.	
Salem		5,516	350.000	None.	
Asbury Park		*5,000	650,000	None.	Summer resort.
Vineland		3,822	*100,000	None.	
Keyport		3,411	50,000	Filtered.	New works.
Freehold		2,932	120,000	None.	
Ocean Grove		2,754	500,000	None.	24 wells. Summer resort.
Atlantic Highlands		945	215,300	Filtered.	Summer resort.
Woodstown		556	50,000	None.	
Short Hills		*500	200,000	None.	
Ocean City		452	100,000	None.	Summer resort.
Seabright		*700	100,000		
Total from Tube Wells		47,919	5,038,300		

From Combined Sources.

Atlantic City	Absecon creek and tube wells	13,055	4,000,000	None.	
Elizabeth	Elizabeth river and tube wells	37,764	3,500,000	Filtered.	River-waters only filtered.
		50,819	7,500,000		

* Estimated.

SUMMARY.

	Population. 1890.	Daily Consumption—Gallons.
Northern Streams by Gravity	225,835	22,930,000
Northern Streams by Pumping	421,845	47,845,000
Delaware by Pumping	142,636	17,210,464
Southern Streams by Pumping	79,616	5,776,597
From Open Wells	26,967	1,540,000
From Tube Wells	47,919	5,038,300
From Combined Sources	50,819	7,500,000
Total for the State	995,637	107,840,361

DAILY CONSUMPTION BY WATER-SHEDS.

	Gallons.
Hackensack Water-shed	6,900,000
Passaic Water-shed above Paterson	34,910,000
Passaic Water-shed below Paterson	28,100,000
Delaware above Trenton	6,110,464
Delaware below Trenton	11,100,000

WORKS IN PROGRESS OR PROPOSED, ETC.

TOWN.	SOURCE.	Population.	REMARKS.
Boonton	Stony brook	4,500	Under construction.
Newton	Morris pond	3,003	Under construction.
Glassboro		*2,000	Proposed.
Hightstown		1,875	Proposed.
Clayton		1,807	Proposed.
Riverside		*1,800	Under construction.
Egg Harbor City		1,439	Contract given.
Deckertown		900	Proposed.
Pemberton		834	In progress.
Point Pleasant		800	Proposed.
Sea Isle City		766	Proposed.
Westwood		500	Franchise granted.
Total		20,224	

* Estimated.

The above tables are prepared from answers to inquiries directed to the proper authorities in each case, and are quite complete. In a few cases, where no response was received, the consumption was estimated from the reports in the Manual of American Water Works, compiled by the "Engineering News." There is at best a wide range in the accuracy with which records of water-supply are kept, ranging from none at all to the most accurate statistics.

In 1882 this Survey made a similar canvass, the results of which were published in the report for that year. From this and the above table we have compiled the table following, which shows the growth of the public water-supply of the State for twelve years. We have estimated the population supplied in each case from census returns and the rate of increase shown thereby, and the result is probably fairly close to the truth. This table enables us to examine the changes which have taken place in this interval, which has been one of the greatest activity in the introduction of public water-supplies:

INCREASE OF POPULATION SUPPLIED AND WATER CONSUMPTION.

Twelve Years.

TOWN.	1882.			1894.		
	Estimated population.	Daily supply —gallons.	Per capita.	Estimated population.	Daily supply —gallons.	Per capita.
Jersey City and towns supplied	127,965	15,921,742	124	222,108	23,000,000	103
Newark	144,698	10,000,000	69	204,558	20,100,000	98
Paterson	56,134	6,000,000	107	94,016	13,000,000	138
Hoboken group	*37,714	4,050,000	108	105,601	6,900,000	66
Camden	44,574	4,500,000	101	67,059	10,000,000	149
Trenton	†40,651	1,275,585	31	74,695	5,610,464	75
Elizabeth	29,922	2,000,000	67	42,109	3,500,000	83
East Orange and Bloomfield	......	None.	......	25,188	1,500,000	60
Orange	......	None.	......	21,670	1,650,000	76
New Brunswick	17,422	1,000,000	57	‡19,161	1,521,097	79
Towns of less than 15,000 inhabitants normally supplied	§62,374	2,796,279	45	143,416	8,545,500	60
All other towns	26,206	1,379,800	53	104,922	12,513,300	120
Total	587,660	48,923,406	83	1,114,403	107,840,361	97

* Includes Hoboken and Hackensack only.
† Includes Chambersburg, annexed later.
‡ A police census in 1894 gives 20,338.
§ Including only those in which the use of water has become general, and excluding summer and winter resorts and uncertain returns.

There is an increased per capita consumption for all towns excepting Jersey City and the Hoboken group. In the case of Jersey City there is a use of about 5,000,000 gallons daily by large industrial establishments, which has probably not increased nearly so fast as the increase in population during this period. This will partly account for the decrease per capita, probably. In the case of the Hoboken group of towns supplied by the Hackensack Water Company, Reorganized, the comparison for the two periods is made between Hoboken and Hackensack only in 1882, and the same places, with a number of smaller residence towns at the present date, and the smaller consumption of these places must be allowed for. It is not unlikely that the same causes which we have mentioned in the case of Jersey City operate here also. A new gravity supply greatly superior in quality to the old one has been introduced in Newark recently, and has been attended by a rapid increase in per capita consumption. Taking all other towns together, we find that the increase in per capita supply averages close to 33 per cent. during this period, ranging from 10 per cent. in Elizabeth to 48 per cent. in Camden. The causes of this increase are partly a much more general use of water, or, in other words, a larger number of water-takers in the total population, and also to an increased use due to sanitary appliances and sanitary measures. In some cases there is little doubt that the amount used is unnecessarily large, and could be reduced if necessary. In general, the per capita consumption increases with the size of the city. There are probably few places of their size in the United States where the consumption is larger than that shown above for Paterson and Camden. The per capita consumption in 1894 in New York City was about 95; in Philadelphia 160 and in Chicago 150, according to an estimate made by "Engineering News." It will be noticed that the figures for New York are close to those shown by Newark, and to the average for the whole State.

The last group in the table classed "All Other Towns" have not a normal supply, or the supply does not bear a normal ratio to the population. Several of these are not fully supplied. For some the returns are considered doubtful, and still others are summer and winter resorts where the average number of people actually supplied is largely in excess of the resident population shown by the census.

Trenton was first supplied in 1783; Morristown in 1799; Newark about 1800; Burlington in 1804, and Mount Holly in 1846. These five places appear to be the only ones supplied with water up to 1850. From 1851 to 1860 water was introduced in Jersey City, Camden, Elizabeth, Hoboken, Paterson, Bordentown and Hackettstown in the order given, making in all 12 places supplied in 1860. From 1861 to 1870 only New Brunswick, Flemington and Millville were added, making 15 in all, while in 1882 thirty-one places were supplied, and in 1894 the total has risen to 81. It will be seen that at present there are very few places with a population of 1,000 that are not supplied with water.

ESTIMATED FUTURE CONSUMPTION.

The urban population of the State is increasing at the rate of 40 per cent. in each decade. It is, of course, impossible to say how long this rate of increase will be maintained, but it seems quite probable that it will not be very considerably less for several decades to come. As the present per capita consumption would seem to be ample for the real needs of the people, we may estimate the increase in the total daily consumption to be at the above rate also, or 40 per cent. in each decade. This gives the following estimate of water needed to supply the State during the next 50 years:

	Population Supplied.	Gallons Daily.
1894	1,114,403	107,840,361
1904	1,560,000	151,000,000
1914	2,180,000	211,000,000
1924	3,050,000	296,000,000
1934	4,270,000	414,000,000
1944	5,980,000	580,000,000

WATER-POWER.

We have already shown, by means of our observations on the Raritan, Passaic, &c., that our estimates in the tables of horse-power available during 9 months of the ordinary dry year, are, in reality, available on an average 9 months in 12 throughout long periods covered by our gaugings, and we may safely assume that this is the real value of our assumed available horse-power. During these 9 months in each year the power will, as a rule, be always available. This, it is to be understood, is the gross horse-power. The efficiency of the best wheels in use is about 80 per cent. under experimental conditions, but with the conditions that obtain in actual operation, even with the best modern wheels thoroughly well set, 75 per cent. of the gross horse-power will be all that can be realized as net horse-power, and it will be more conservative to consider 70 per cent. as the amount really effective. The economy of the use of water-power is to be measured by the cost of producing one horse-power by steam. This, of course, varies with the price of fuel and the efficiency of the engines and boilers. With coal at $3 per ton on the ground at the boilers, Dr. Charles E. Emery estimates the cost of operating expenses per horse-power, including repairs, supplies, fuel and labor annually at the rate shown in the following table. The first column gives the operating expenses per year, as above explained, and the second column the entire capital necessary to set up the plant and maintain one horse-power per annum, estimating interest at the rate of 5 per cent.:

COST OF ONE NET HORSE-POWER PER YEAR OF 310 DAYS OF 10 HOURS EACH.

Total Horse-Power in Use.	Cost of One Horse-Power in Wages, Fuel, Repairs, Supplies, Insurance and Taxes.	Capital Necessary to Maintain One Horse-Power at 5 per cent. Interest.
75	$37.65	$891.52
100	36.27	856.74
150	32.25	764.67
200	29.80	708.79

For continuous power, the cost of operation will be almost exactly twice the above.

It will be seen that the cost varies with the size of the plant, and this is found to be true in general practice. A very large power plant is that used for pumping water at the city of Philadelphia, and the following figures have been computed from the records of the Philadelphia Water Department from 1887 to 1893, inclusive, and give the actual yearly cost of producing one continuous horse-power under conditions extremely favorable to a low cost. This includes labor, fuel, supplies and repairs for one net horse-power per annum:

Cost of steam-power	$78 53
Cost of water-power	24 47
Saved per horse-power by water-power	$54 06

It is safe to say that, excepting by an improbable decrease in the cost of coal, there are very few cases in which the cost of one horse-power will be less than that shown by the above figures. In fact, it is known to be considerably greater at most of our establishments using steam-power. It is, perhaps, unwise to multiply figures, and it will suffice and be measurably accurate and certainly conservative if we assume that the cost of producing one net horse-power per annum will be at least $50 less by water-power than by steam-power for continuous power day and night, and for working hours annually at ten hours daily we shall not be far out of the way if we assume the saving at $25 per net horse-power, not including interest on the cost of plant, depreciation, taxes or insurance, which may, for our present purposes, be assumed to be equal in both cases.

The cost of installing a steam plant with all appurtenances may be taken to range from $80 to $90 per net horse-power for plants of from 100 to 200 horse-power. If we capitalize the above saving of operating expenses at 6 per cent. per annum, and add the cost of the plant, the average capitalized value of one continuous horse-power may be taken to be $920 if measured by the cost of steam-power, consequently, other things being equal, we may lay out in developing water-power $920 per net horse-power; or, estimating the efficiency at 70 per cent., $644 for each gross horse-power of continuous power before water-power will cost as much as steam-power. It will often be possible to develop for much less than this even when only the minimum power of the stream is taken into account, and the surplus power during the wetter months of the year, if it can be profitably used, will be sufficient to give a good profit on the outlay. There are so many determining factors in the problem, however, that it is impossible to lay down any general rule as to the comparative economy of the use of water-power. Some industries can profitably use power which is available only six months in the year, and they are usually those employing a large amount of power in proportion to the number of the operatives, such as paper and flouring mills. By taking advantage of favorable conditions, there is no doubt that there is still a field for the development of water-power in the State, and this field promises to be enlarged with the introduction of electric transmission, which will give more latitude in the location of establishments using water-power, thus doing away with one of its occasional disadvantages.

In view of the above facts, therefore, all of the figures which we give are to be regarded rather as illustrations than as actual measurements of what may be profitably expended in developing water-power or of its actual value as applied to specific cases. As our estimated available power is for only nine months of the year, if it becomes necessary to furnish auxiliary steam-power, a less sum can be expended profitably in the development of the water-power plant. If we assume an average cost of $90 per net horse-power to cover the installation of a steam plant, and $78 per annum as the operating expenses of steam-power, and $25 per annum for water-power, the outlay admissible in developing a water-power plant before it becomes as expensive as steam-power will be about as follows for 100 net horse-power under the different conditions assumed. From this it appears that the outlay may be from $66,250 to $97,333, and, in the second case, which is a fair average assumption, $86,617. As there are very many opportunities to develop this amount of power for much less than this outlay, the resulting saving must be weighed against any possible disadvantages of location, larger capital needed, &c.:

ADMISSIBLE OUTLAY IN DEVELOPING ONE HUNDRED NET HORSE-POWER OF WATER-POWER BEFORE IT BECOMES AS EXPENSIVE AS STEAM-POWER, AND OPERATING EXPENSES OF THE SAME UNDER DIFFERENT DEGREES OF PERMANENCE OF WATER-POWER.

Plant with steam-power only.

Cost of plant	$9,000	
Interest on same at 6 per cent		$540
Operating expenses at $78 per horse-power		7,800
Total cost, exclusive of depreciation		$8,340

Plant with water-power only.

Admissible cost of plant	$97,333	
Interest on same at 6 per cent		$5,840
Operating expenses at $25 per horse-power		2,500
Total cost, exclusive of depreciation		$8,340

Plant with water-power 9 months, and auxiliary steam-power 3 months, averaging 20 horse-power with a maximum of 70 horse-power for use in the driest month, being the usual conditions on New Jersey streams.

Admissible cost of water-plant	$86,617	
Cost of 70 horse-power steam plant	6,300	
Total cost of plant	$92,917	
Interest on same at 6 per cent		$5,575
Operating expenses, 20 horse-power, steam, 3 months, at $78 per annum		390
Operating expenses, 100 horse-power, water, 9 months, at $25 per annum		1,875
Operating expenses, 80 horse-power, water, 3 months, at $25 per annum		500
Total annual cost, exclusive of depreciation		$8,340

Plant with water-power 9 months and steam-power 3 months.

Admissible cost of water plant	$66,250	
Cost of steam plant	9,000	
Total	$75,250	
Interest on same at 6 per cent		$4,515
Operating expenses, 100 horse-power, water, 9 months		1,875
Operating expenses, 100 horse-power, steam, 3 months		1,950
Total cost of operating, exclusive of depreciation		$8,340

RENTAL VALUE OF WATER-POWER.

Perhaps no better standard of that value exists than the figures of rental per horse-power given in the census report on water-power, 1880, for the leading water-powers of the United States. The following list is extracted relating to powers in this section of the country:

TURNER'S FALLS, MASSACHUSETTS.

Connecticut River. Turner's Falls Company, Owner.

Available power equals 17,600 theoretical horse-power in low water of ordinarily dry years, night and day.

Rates for Power.—Usual rate has been $7.50 per annum per horse-power (not further specified), but there is no established rate for the future.

BELLOWS FALLS, VERMONT.

Connecticut River. Bellows Falls Canal Company, Owner.

Available power equals 12,000 theoretical horse-power in low water of ordinarily dry years, night and day.

Rates for Power.—Nominal rate, $7.50 per annum per horse-power (not further specified).

UNIONVILLE, CONNECTICUT.

Farmington River. Union Water-Power Company, Owner.

Available power equals 860 theoretical horse-power in low water of ordinarily dry years, night and day.

Rates for Power.—Perpetual lease at $175 per mill-power per annum, a mill-power being 7½ cubic feet per second under a head of 18 feet, or 15.34 theoretical horse-power—that is, the price is $11.35 per theoretical horse-power per annum.

OCCUM, CONNECTICUT.

Shetucket River. Norwich Water-Power Company, Owner.

Available power equals 290 theoretical horse-power in low water of ordinarily dry years, night and day.

Rates for Power.—Twenty dollars per annum per horse-power (not further specified).

BARRETT'S JUNCTION, MASSACHUSETTS.

Swift River. Barrett's Junction Water-Power Company, Owner.

Available power equals 200 theoretical horse-power in low water of ordinarily dry years, night and day.

Rates for Power.—Nine dollars per annum per horse-power (not further specified).

BIRMINGHAM, CONNECTICUT.

Housatonic River. Oosatonic Water Company, Owner.

Available power equals 1,375 theoretical horse-power in low-water of ordinarily dry years, night and day.

Rates for Power.—Power leased for 99 years, per square foot. *Permanent water,* $20 per annum per theoretical horse-power; *second surplus,* $8 per annum per theoretical horse-power. Company does not guarantee power in any case.

ANSONIA, CONNECTICUT.

Naugatuck River. Ansonia Land and Water-Power Company, Owner.

Available Power.—Total effective (rated) power of wheels in use, 1,600 horse power.

Rates for Power.—Water leased by the square foot, under a head of 30 inches, estimated to produce 30 theoretical horse-power. *Permanent water,* $600 per annum per square foot; *surplus water,* $250 to $500 per annum per square foot ($20 per annum per horse-power).

COHOES, NEW YORK.

Mohawk River. The Cohoes Company, Owner.

Available power equals 9,450 theoretical horse-power in low water in ordinarily dry years, night and day.

Rates for Power.—Perpetual lease of land and power with reserved rent amounting to $14.67 per annum per theoretical horse-power.

LOCKPORT, NEW YORK.

Erie Canal. Lockport Hydraulic Company, Owner.

Available power equals 2,590 to 3,238 theoretical horse-power.

Rates for Power.—Perpetual lease or absolute purchase. Price, from $8.33 to $11.11 per annum per theoretical horse-power.

PASSAIC, NEW JERSEY.

Passaic River. Dundee Water-Power and Land Company, Owner.

Available power equals about 800 theoretical horse-power in low seasons of ordinarily dry years, night and day.

Rates for Power.—About $33.33 per annum per gross or theoretical horse-power, for 12 hours a day.

PATERSON, NEW JERSEY.

Passaic River. Society for Establishing Useful Manufactures, Owner.

Available power equals about 2,150 theoretical horse-power in low season of ordinarily dry years, night and day.

Rates for Power.—Seven hundred and fifty dollars per annum per square foot of orifice, under a head of 2.75 feet to center, equivalent to about $36 per annum per theoretical or gross horse-power.

RARITAN, NEW JERSEY.

Raritan River. Raritan Water.Power Company, Owner.

Available power equals 216 theoretical horse-power in low season of ordinarily dry years, night and day.

Rates for Power.—Nominal price, $300 to $400 per annum per square foot of orifice, under a head of 30 inches to center of orifice.

TRENTON, NEW JERSEY.

Delaware River. Trenton Water-Power Company, Owner.

Available power equals 3,000 to 4,500 theoretical horse-power in low seasons of ordinarily dry years, night and day.

Rates for Power.—Three and four dollars per square inch, under a head of 3 feet; equivalent to about $37.50 and $50 per annum per theoretical horse-power.

FREDERICKSBURG, VIRGINIA.

Rapahannock River. Fredericksburg Water-Power Company, Owner.

Available power equals 3,000 to 4,500 theoretical horse-power in low season of ordinarily dry years, night and day.

Rates for Power.—From $5 to $15 per horse-power (not further specified).

MANCHESTER, VIRGINIA.

James River. City of Manchester, Owner.

Available power cannot be stated.

Rates for Power—Fifty-year leases at $4 per annum per square inch of orifice, under a head of 3 feet; corresponding, theoretically, to between $29.60 and $42.10 per annum per theoretical horse-power, according as the fall is 22 or 14 feet.

We find from the above that the highest rentals are obtained in our own State, and that these range from about $30 to $50 per annum per gross or theoretical horse-power. Thirty dollars would be a conservative rental value for the more populous portions of the State, and there are very few places where it would be less than $20 per annum with the excellent transportation facilities which now exist everywhere.

COMPARATIVE ECONOMY OF STORAGE RESERVOIRS AND AUXILIARY STEAM-POWER.

Water has often been stored in order to maintain the flow of a stream during the dry season for water-power purposes. We may obtain an approximate idea of the economy of this from the following figures. Let us take, for example, Table No. 53, on page 157. We find that we can obtain for 9 months from 1 square mile .044 gross horse-power for each foot of fall, or at 70 per cent. efficiency .031 horse-power for each square mile of water-shed. In order to maintain this throughout the driest period, we shall need 1.14 inches of storage, or 19,800,000 gallons. For one net horse-power, therefore, we shall need 640,000,000 gallons, and at $170 per 1,000,000 gallons (being Mr. J. J. R. Croes' estimate of the average cost of storage on the Croton water-shed, which is, however, a high allowance for storage for water-supply purposes), this would cost $108,800. To provide auxiliary steam-power and operate the same for three months it will cost, capitalized at 6 per cent., $415 per net horse-power. It is therefore evident that storage at these figures would not be as economical as auxiliary steam-power until the fall was 262 feet. Probably with a less fall than 100 feet it will rarely be as economical to store water as to provide an auxiliary steam plant, even under the most favorable circumstances.

It is evident that water-power requires a larger original outlay than steam-power, and there is no doubt that the necessity for larger capital frequently militates against its employment, even when economy of operation is undoubtedly in its favor.

Peter Hasenclever, of the London Company, has the credit of inaugurating the practice of utilizing the Highland lakes for storage for water-power which prevailed so generally during the progress of early iron manufacturing in the State. We find the following curious reference to this in the report of a commission sent out from England in 1768:

> "He is the first person we know who has so greatly improved the use of the great natural ponds of this country, as by damming them to secure reservoirs of water for the use of the iron works in the dry season, without which the best streams are liable to fail in the great droughts we are subject to."

This is one of the many references which we have found indicating that the "great droughts" were as troublesome during the last as they have been during the present century.

EVAPORATION—GROUND-STORAGE EFFECTS OF VEGETATION.

THE LAWS WHICH GOVERN EVAPORATION.

We gave, at the beginning of our report, certain experimental measures of evaporation. It will be noticed that we have made rather sparing use of these, although they have been valuable guides in making up our evaporation formula. We have concluded, from the results of these studies, that as a rule it is impossible to even approximate in experience the conditions which exist on a large scale in nature. We believe, therefore, that there is only one way to obtain an accurate estimate of the water evaporated and consumed by vegetation under the conditions which obtain in nature, and that is by careful gaugings of streams with known drainage area, accompanied by rainfall measurements and temperature observations. This is conducting our evaporation experiments on a larger scale, and under conditions which can be obtained in no other way. Inasmuch as our evaporation formulæ are obtained from the results of the best measurements of this kind which are available, they should give us valuable knowledge of evaporation as it actually exists within the State, although we do not claim for these empirical formulæ absolute accuracy.

Our estimates of evaporation for the average, the ordinary dry and the driest year, for various parts of the State, are given in Table No. 46 (page 114 *et seq.*) These include, under the term "Evaporation," direct evaporation by the atmosphere, and also the water consumed by vegetation, a large part of which is also thrown off eventually to the atmosphere. Our studies appear to indicate the primary and overpowering influence of temperature upon the amount of water evaporated. In this our results conflict with a rule that has been much followed, of considering the evaporation to vary with the topography of the country, for this is the real meaning of the estimates which make the available run-off of streams vary from 80 or 90 per cent. of rainfall on steep mountain slopes to 40 per cent. on flat, cultivated lands and prairies. We shall now endeavor to further illustrate and elucidate our reasons for subordinating the effects of flatness, marshiness, cultivation, &c., to the more potent effect of temperature.

The following table is prepared from data quoted by M. Becquerel, from Schubler, in his admirable paper on the effect of forests upon climate, stream-flow, &c., a translation of which is given in the report upon forestry made in 1878 to the United States Minister of Agriculture by F. B. Hough. It may be said here that this paper admirably digests and draws all the legitimate conclusions possible from experimental data obtained under the usual conditions, and we prefer to refer the reader to this and other parts of Mr. Hough's report rather than quote extensively from experiments upon evaporation from soil in forests and in open country, and similar observations which we do not believe are applicable to our problem:

CAPACITY FOR ABSORPTION AND YIELDING UP OF WATER POSSESSED BY VARIOUS SOILS.

	Water Absorbed by 100 Parts of Soil after Drying at 40° or 50°.	Percentage of Water Evaporated in 4 Hours at 56.7° F.	Parts of Water in 100 Parts of Soil Evaporated in 4 Hours.
Silicious sand	25	88	22
Gypseous soil	27	......	......
Calcareous sand	29	75.9	22
Barren clay	40	52	21
Fertile clay	50	45.7	23
Loamy clay (or clayey soil)	60	34.9	21
Pure clay	70	......	......
Fine calcareous soil	85	28.6	24
Humus	190	20.2	38
Magnesian soil	156	......	......
Garden soil	89	......	......

This table shows that the capacity of different soils for absorption is almost inversely as their capacity for giving up water to evaporation, and we have brought out by the third column a curious fact that the ratio of the water evaporated in a given time to the whole volume of soil is very nearly a constant one, averaging 22 per cent., excepting in the case of humus, where it is 38 per cent., but it must be remembered that this is based upon the dry soils, whereas the volume of humus when wet is considerably greater. We shall have more to say later as to the part played by this humus in the effect of forests upon the flow of streams. The lesson which we wish to enforce from this table at present is, that from all these different kinds of soil, the actual amount of water evaporated in a given time is very nearly the same. It may be inferred that the kind of soil has much less to do with the amount of evaporation than has the temperature.

It will be seen that our evaporation formulæ are, in every case, made up of a constant and a variable term, the variable being a proportion of the rainfall. The reason for this is explained by the difference between evaporation from water and that from land. This is probably, in our latitude, at least, about the same as the difference between the average of Mr. Fitzgerald's table of evaporation from water and our evaporation for the average year on the Passaic watershed, the latter being the result of actual observations of the difference between rainfall and total run-off on the Sudbury, Croton and

Passaic. This gives us 39.6 inches per annum from water, against 22.7 inches from land, the latter being about 57 per cent. of the former. This relation varies, however, for different seasons, the above figures being yearly averages. Our evaporation increases or decreases slightly with the rainfall, therefore, because of a more rapid evaporation when the ground is full of water, and particularly when the surface is actually wet. In excessive, heavy rainfall, the water may actually stand on the surface in shallow pools, which has still more effect in quickening evaporation.

We have not the means at hand by which to accurately separate the demands of evaporation proper from those of vegetation, and we doubt if there can be any such accurate apportionment, as we must remember that the exhalation of moisture by the plants goes to help satisfy the demands of a dry atmosphere, consequently if there were no vegetation it is not improbable that the evaporation from the bare earth alone would equal the combined draught of vegetation and evaporation shown by our table.

If we remember that from November to April the demands of vegetation are practically nothing upon the Passaic water-shed, this may be taken as a measure of the evaporation from earth under a temperature equal to the average of these six months. From the table on page 117 we find the total evaporation for these months during the average year is 4.91 inches, or 2.45 inches for each three months, the mean temperature during this period being 35.7 degrees. We may estimate, therefore, the proportionate evaporation for each season of the year, exclusive of the demands of vegetation, to be 2.45 inches, increasing 5 per cent. for each degree the temperature is above 35.7 degrees, and decreasing at the same rate for lower temperature. In this way we have computed the first column of evaporation in the following table. The next column is that of the average year on the Passaic water-shed, including the demands of vegetation, and the last column, showing the difference between these two, gives the probable demands of vegetation alone on this assumption. We see that the total amounts to about 6 inches per annum, and taking the growing season only, which may be regarded as including the months from May to August, it is 5.44 inches, or at the rate of 1.36 per month:

	Temperature—Degrees Fahrenheit	Computed Evaporation from Earth—Inches.	Evaporation for Average Year, Including Vegetation—Inches.	Probable Demands of Vegetation Alone—Inches.
Winter	29.5	1.69	2.05	.36
Spring	47.2	3.86	4.51	.65
Summer	70.2	6.68	11.47	4.79
Autumn	51.9	4.44	4.67	.23
Year	49.7	16.67	22.70	6.03

In our analysis of long-series gaugings, we show by Table No. 29 that evaporation on the Sudbury, Croton and Passaic water-sheds is always the same for a given rainfall, these three water-sheds having about the same mean temperature. If we remember that the area not in forest is, in each case, under about the same kind of cultivation, including the usual farm crops, with a considerable percentage of pasture lands—on the whole, not unlike the distribution given in Table No. 19 for Sussex county—the percentage of forest on each of these water-sheds becomes a guide to the character of the vegetation. We have, on the Sudbury, about 14 per cent. of forest, on the Croton, about 30 per cent. and on the Passaic, 44 per cent. It appears, therefore, that this range of from 14 to 44 per cent. in the amount of forest, with the attendant difference in other vegetation, has no effect whatever upon the evaporation, so far as our gaugings indicate. In respect to topography, steepness of slopes, marshiness, &c., there is no very great difference upon these water-sheds. The average amount of forest for the three is about 40 per cent. Neshaminy creek, in Pennsylvania, has a flatter water-shed and entirely different soil and only 7 per cent. in forest, the remaining 93 per cent. being under a much higher state of cultivation, the distribution resembling more closely that of Table No. 18 for Somerset county. The mean temperature is two degrees in excess of that of the Croton, Passaic and Sudbury, and the corresponding excess of evaporation would be 10 per cent. On pages 92 and 93 will be found the computed and observed flow of the stream during two years, based on this increased evaporation, and the agreement is seen to be close. If we did not know from other cases that this increase was due to temperature, it might be ascribed to the higher cultivation and the less proportion of forest. The Perkiomen has about 25 per cent. of its drainage area in forest. Owing to a lack of temperature data, we have ascribed to this water-shed in our estimates the same mean temperature as the Neshaminy, but its average elevation is about 200 feet higher, and from this and its more westward location we should be inclined to expect that the mean temperature was really about one degree less. We find in our comparison of flow, computed on the assumption that the mean temperature is the same as that of the Neshaminy, a general excess of about 10 per cent. of observed flow over computed. The above-mentioned correction of mean temperature would account for one-half of this difference. The remainder may possibly be due to the larger extent of forest, but this is rather a possibility than a probability. The Connecticut, with 53 per cent. of forest, shows a decrease of evaporation, which is also fully accounted for by the difference in mean temperature, so that from the comparatively flat and highly-cultivated Neshaminy water-shed to the mountainous and forested, or, at least, much less highly-cultivated water-shed of the Connecticut, the difference in mean temperature is entirely adequate to account for the difference in evaporation, and we believe there are few careful students of the subject who will not prefer the difference in temperature to the difference in vegetation or topography as a reason for the decreased evaporation.

Turning now to our own State, we have made comparisons in Tables Nos. 47 to 50 of the evaporation computed by our formula, based on the Passaic, Croton and Sudbury gaugings, and the mean temperature and the evaporation actually observed by our gaugings. We find that the Highland streams, excepting the Ramapo, show from 5 to 15 per cent. less evaporation than the Passaic, Croton and Sudbury, whereas the difference in mean temperature of this whole district would call for 11.5 per cent. less evaporation. Not only is the general agreement entirely satisfactory, but the range is fully accounted for by the differing mean elevation of the water-sheds and the attendant difference in temperature. In fact, we may go so far as to say that the gaugings actually indicate the mean temperature of the water-sheds more closely than we can obtain it from the available temperature observations. The Raritan gaugings show a mean excess of 4.3 per cent. of evaporation over that of the Passaic, while the exact difference of mean temperature is 0.9 degrees, equivalent to a difference of 4.5 per cent. in evaporation. The Hackensack gaugings show an average excess of 3.8 per cent., and while we have assumed the mean temperature to be the same as the Raritan for convenience, as a matter of fact it is highly probable that even this slight decrease from the figures for the Raritan could be accounted for by a slightly lower temperature. The Hackensack and the Raritan, therefore, respond equally well to the difference in mean temperature, although the former has 60 per cent. in forest and a considerable extent of marsh land, and the remainder is not under a very high state of cultivation, whereas the Raritan water-shed is only 13 per cent. in forest, is entirely free from marshes and is very highly cultivated. It will be noted that in this comparison there is an absolute lack of any correspondence between the amount of evaporation and the character of the vegetation of the water-shed, its soil or topography.

The Great Egg Harbor and Batsto represent the widest divergence which we have reached from the mean temperature of the Passaic, &c. We estimate that this difference should cause an increase of 14 per cent. in evaporation, and we find from our gaugings that the evaporation is actually increased to even a greater extent than this, due to the fact that the difference in temperature is not equal throughout the year, in the face of the fact that 88 per cent. of these water-sheds is in forest and only 12 per cent. under cultivation. We have here not only convincing evidence of the paramount influence of temperature, but, as in the case of the Highland streams, it is seen that the response of evaporation to temperature is delicate and exact. It seems, therefore, that the data which we have in hand go far to prove that evaporation is effected principally by temperature, and to an entirely subordinate extent by the character of the vegetation or the topography of the water-shed. The force of this is apparent when we bear in mind that rainfall, less evaporation, as we have considered it, gives the amount of water which will flow off in the streams.

It becomes interesting to note what rainfall is necessary to be just equivalent to the demands of evaporation and vegetation. We have given in the previous table the temperature of the Passaic water-shed by seasons. By the use of this we may arrange our evaporation formula by seasons. They become as follows:

Winter .... E equals $(.99 + .10\,R)\,(.05\,T - .475)$
Spring .... E “ $(3.22 + .13\,R)\,(.05\,T - 1.36)$
Summer .... E “ $(8.12 + .27\,R)\,(.05\,T - 2.51)$
Autumn .... E “ $(3.17 + .14\,R)\,(.05\,T - 1.595)$

Year .... E equals $(15.50 + .16\,R)\,(.05\,T - 1.485)$

If we now introduce into these equations the proper values for T, and make E equal R, we obtain the following values of rainfall needed to equal the evaporation:

	Highlands and Kittatinny Valley.	Passaic Water-shed.	Red Sandstone Plain.	Southern New Jersey.
Winter	.97	1.10	1.16	1.27
Spring	3.19	3.70	3.91	4.31
Summer	9.46	11.12	11.97	13.37
Autumn	3.21	3.96	3.90	4.31
Year	16.83	19.61	20.94	23.26

It is seen that, excepting in summer, the rainfall in the State will usually be largely in excess of evaporation, but if the summer rainfall is less than about 12 inches it will be entirely evaporated. Inasmuch as most of our streams carry off about 2 inches of ground-water per month, we shall require 6 inches in excess of the above for each season in order to maintain full ground-water, but we may remark here that we shall show more fully later that this condition is not desirable for healthful vegetation. Indeed, we shall show that the water drawn from the earth by stream-flow is not at all necessary, but in fact is detrimental to vegetation. There are two distinct operations by which depletion of ground-water is brought about. There is the draining process, which relieves the ground of water which fills the voids, and there is the drying process of evaporation and vegetation, which takes up the remaining water held in the earth by capillary attraction.

It will be noted that for the more productive part of the State, having a mean temperature of about 50 degrees, about 20 inches per annum of rainfall is needed to satisfy the requirements of evaporation and vegetation. It is of interest that our evaporation formulæ so closely conform to general observation, which is to the effect that for about this temperature less than 20 inches of annual rainfall is accompanied by an exclusively pastoral condition of the country, and when the rainfall becomes as small as 14 inches vegetation practically disappears. These facts in all respects agree with the indications of our evaporation formula. In Kansas, when the rainfall sinks as low as 20 inches, it also has a distribution through the season to some extent like that of the above table, or about as follows: Winter, 2.7; spring, 4.7; summer, 7.9, and autumn, 4.7 inches.

While they are not exactly germane to the subject of water-supply and water-power, these facts which we learn from the condition of vegetation, in a general way, confirm the accuracy of our assumptions. They are, besides, of the greatest economic importance, so that we may be pardoned if we pursue them a little farther, as our formulæ are probably the first attempt at computation of evaporation based upon proper data. From Table No. 46 we have prepared the following table of seasonal rainfall and evaporation. As the growing period is confined almost exclusively to spring and summer, we have not considered it necessary to include the other seasons:

SPRING AND SUMMER RAINFALL AND EVAPORATION.

Average Year.

	SPRING.			SUMMER.		
	Rain.	Evaporation.	Difference.	Rain.	Evaporation.	Difference.
Kittatinny valley and Highlands.........	10.93	4.18	+6.75	12.35	10.09	+2.26
Passaic water-shed............................	11.15	4.51	+6.64	12.60	11.47	+1.13
Red sandstone plain...........................	11.39	4.99	+6.40	12.86	12.14	+ .72
Trenton to Camden............................	11.71	5.47	+6.24	13.22	13.28	— .06
Camden to Bridgeton..........................	11.38	5.42	+5.96	12.84	13.15	— .31
Coast streams....................................	12.17	5.56	+6.61	13.76	13.70	+ .06

Ordinary Dry Year.

Kittatinny valley and Highlands.........	8.73	3.91	+4.82	11.84	9.99	+1.85
Passaic water-shed............................	8.91	4.45	+4.46	12.13	11.37	+ .74
Red sandstone plain...........................	9.13	4.71	+4.42	12.37	12.00	+ .37
Trenton to Camden............................	9.33	5.13	+4.20	12.63	13.12	— .49
Camden to Bridgeton..........................	9.13	5.11	+4.02	12.37	12.55	— .18
Coast streams....................................	9.69	5.18	+4.51	13.17	13.27	— .10

Driest Year.

Kittatinny valley and Highlands.........	7.15	3.72	+3.43	6.01	8.56	—2.55
Passaic water-shed............................	7.15	4.20	+2.95	6.01	9.58	—3.57
Red sandstone plain...........................	7.15	4.41	+2.74	6.01	10.15	—4.14
Trenton to Camden........................	7.15	4.79	+2.36	6.01	11.03	—5.02
Camden to Bridgeton....						
Coast streams...............................						

The conditions shown in the above table may be described as follows: The average year presents those which are most favorable to the generally-abundant vegetation of the State; the ordinary dry year gives conditions of scanty rainfall, but not such as to cause general distress to plant-growth, while the driest year makes exceedingly distressing conditions, and such that, if they were continued, would change the whole character of the vegetation of the State. This was based upon the year 1881, which was not only a ruinous one for ordinary crops, but caused the death of numbers of forest trees, and those which did not actually die had their foliage browned as if by fire in many portions of the State. The same thing happened in a part of northern New Jersey to a less degree, in 1894, when the conditions of rainfall and evaporation were as follows:

1894.	Rain.	Evaporation.	Difference.
Spring	9.45	4.45	+5.00
Summer	6.22	9.80	—3.58

The deficiency above shown for the summer is about the same as that on the Passaic water-shed for the driest year. Should these conditions continue, it is evident that our forest growth would become scanty. Here again it is interesting to compare those conditions which prevail in the west, at about the line where the forest growth ceases to be abundant because of scarcity of rainfall. This is at about 32 inches annually in the neighborhood of Kansas, whereas the rainfall for our driest year is 31.63 inches. The rainfall and computed evaporation by seasons in Kansas at about the limit of abundant forest growth is approximately shown in the following table:

	Temperature.	Rain.	Computed Evaporation.	Difference.
Winter	29	4.3	1.4	+2.9
Spring	54	7.6	5.7	+1.9
Summer	75	12.6	14.4	—1.8
Autumn	54	7.5	4.6	+2.9
Year	54	32.0	26.1	+5.9

The actual effect on vegetation of such dryness is probably the more accurately shown by the depletion of the ground-water, which we shall consider hereafter. The roots of some of the plants penetrate to a great depth, and are consequently able to extract moisture to a corresponding depth. Thus the roots of common clover, a comparatively small plant, have been traced to a depth of four feet. In extremely dry times we have known the earth to become entirely dry to a depth of at least three feet, and there is no doubt that in some soils on the higher portions of a water-shed this depth is considerably exceeded.

GROUND-WATER.

Our flow from storage, as shown by the storage curves which we have used in computing the flow of streams, includes, in addition to the ground-water, some water drawn from ponds and swamps which could not be separated. We have seen that the Paulinskill has a pond storage amounting to 0.7 inches on the water-shed. It is much less on other Kittatinny valley water-sheds. The whole Passaic, during the period covered by our gaugings, had about 10 square miles of water surface, or 1.2 per cent. of the whole, and an average draught of 24 inches on these ponds would give 0.29 inch on the water-shed. The Ramapo has 1.2 per cent. of water surface; the Wanaque 3.4 per cent.; the Pequannock 1 per cent., and the Rockaway above Boonton about 2 per cent. of water surface. The Raritan has almost none, as is the case for the southern streams, although these have large swamp-storage. This pond-storage has some effect upon the storage curves, as we have remarked, but as the draught is somewhat irregular it was necessarily to a large extent eliminated, so that in the main the storage curves represent natural ground and swamp-storage. The depletion of ground-water is usually due to evaporation and drainage to streams combined, but if we consider the demands of evaporation to be just equal to the rainfall, and on this assumption compute the flow of different streams for a series of months, we shall have a pretty accurate idea of the amount of water which may be extracted from the earth by drainage alone, and also a good measure of the relative capacity of different kinds of soil and subsoil for feeding the streams.

FLOW FROM GROUND-WATER WHEN RAINFALL EQUALS EVAPORATION.

MONTH.	HIGHLANDS AND KITTATINNY VALLEY.		PASSAIC WATERSHED.		HACKENSACK AND N. E RED SANDSTONE.		RARITAN WATERSHED.		SMALL RED SANDSTONE WATERSHEDS.		COAST STREAMS.	
	Flow.	Depletion.	Flow.	Depletion.	Flow.	Depletion.	Flow.	Depletion.	Flow.	Depletion.	Flow.	Depletion.
First	1.20	1.20	1.16	1.16	1.60	1.60	1.43	1.43	.94	.94	1.76	1.76
Second	.55	1.75	.54	1.70	.93	2.53	.64	2.07	.38	1.32	1.38	3.14
Third	.39	2.14	.40	2.10	.77	3.30	.45	2.52	.26	1.58	1.30	4.44
Fourth	.32	2 46	.33	2 43	.73	4.03	.35	2 87	.20	1.78	1.02	5.46
Fifth	.27	2 73	.32	2.75	.66	4.69	.30	3.17	.14	1.92	.63	6.09
Sixth	.25	2 88	.31	3 06	.54	5 23	.27	3.44	.12	2 04	.46	6.55
Seventh	.23	3.21	.30	3.36	.40	5.63	.25	3.69	.10	2.14	.38	6 93
Eighth	.22	3.45	.29	3.65	.34	5.97	.23	3.92	.08	2.22	.34	7.27
Ninth	.21	3.64	.28	3.93	.28	6.25	.22	4.14	.07	2 29	.32	7.59
Total	3.64	....	3.93	....	6.25	....	4.14	....	2.29	....	7.59	....

As the growing season lasts about four months, or from May to August, and the depletion of ground-water usually begins about May 1st, we have, in the figures for the fourth month above, the amount of water extracted by the streams alone, when, as is not at all unusual during these months, the rainfall is only equal to the evaporation. It will be noted from the total for nine months that the capacity of the streams for depleting ground-water is limited. As we have previously remarked, the water included in the above table is drainage, or the surplus water held in the voids, and not needed for plant-growth. In fact, this water is that which is troublesome to the agriculturist, and when nature has not provided a ready outlet for it he finds it necessary to underdrain his fields and thus remove it. He has found it necessary to remove it to a depth of about three feet, and in order to effect this he usually places such drains at a depth of four feet. Its presence probably prevents the necessary penetration of air into the soil to oxidize its organic matters. A soil which is not deprived of this water of drainage has a low temperature, a difference of 10 degrees having been observed at a depth of 7 inches between drained and undrained soils. We may expect, therefore, that a country in which the depletion of ground-water is large will be characterized by a warm soil, as is the case with southern New Jersey.

We may conclude, therefore, that the water drawn off by streams is not, as a rule, any part of that which is necessary to support the demands of vegetation, but that these demands may be supplied from the water held in the soil after such drainage is effected.

The following table shows the extent to which ground-water is actually depleted in different sections of the State during our average, ordinary dry and driest years:

AVERAGE DEPLETION OF GROUND-WATER AT END OF EACH MONTH, MEASURED BY THE INCHES OF RAIN NEEDED TO REPLENISH IT.

Average Year.

	May.	June.	July.	August.	September.	October.	November.	December.	January.
Kittatinny Valley and the Highlands	.27	.73	1.23	.86	.47	full.	....	....	....
Passaic Water-shed	.36	.97	1.65	1.38	1.61	.32	full.	....	....
Hackensack Water-shed	.75	1.68	2.81	2.97	2.55	1.43	.39	full.	....
Raritan Water-shed	.64	1.42	2.26	2.10	1.48	.52	full.	....	....
Small Red Sandstone Water-sheds	.28	.79	1.44	1.14	.49	full.	....	....	....
Trenton to Camden	.87	1.92	3.36	3.78	3.50	2.32	.79	full.	....
Coast Streams	.82	2.19	3.95	4.66	4.59	3.67	2.25	.78	full.

Ordinary Dry Year.

	April.	May.	June.	July.	August.	September.	October.	November.	December.	January.
Kittatinny Valley and Highlands	.30	.60	.96	1.17	1.21	2.31	1.65	.89	full	......
Passaic Water-shed	.30	.72	1.22	1.62	1.74	2.90	2.26	1.33	full.	......
Hackensack Water-shed	.61	1.31	2.14	2.99	3.53	5.10	4.70	4.02	1.62	full.
Raritan Water-shed	.49	1.08	1.72	2.28	2.50	3.70	3.02	2.05	full.	......
Small Red Sandstone Water-sheds	.18	.53	.97	1.37	1.45	2.48	1.63	.67	full.	......
Trenton to Camden	.64	1.36	2.42	3.65	4.47	6.02	5.55	4.53	2.13	full.
Coast Streams	.61	1.59	2.93	4.47	5.42	6.88	6.34	5.51	3.40	1.20

Driest Period.

	April.	May.	June.	July.	August.	September.	October.	November.	December.	January.	February.	March.
Kittatinny Valley and Highlands	1.32	1.34	1.49	3.71	5.28	6.09	4.20	3.14	1.43	full.	....	....
Passaic Water-shed	1 35	1.58	1.65	4.35	6.34	7.47	5.92	5.01	3.31	full.	....	....
Hackensack Water-shed	1.87	2.57	3.11	6.20	8.23	9.42	7.90	7.00	5.31	2.23	.09	full.
Raritan Water-shed	1.67	2.07	2.31	5.04	7.08	8.20	6.61	5.65	3.92	.58	full.	....
Small Red Sandstone Water-sheds	1.46	1.54	1.55	4.09	6.01	7.02	5.32	4.24	2.36	full.	....	....
Trenton to Camden	1.91	2.86	3.79	7.04	9.49	10.92	9.59	8.84	7.29	4.02	1.49	.34
Coast Streams	2.13	3.51	4.86	8.07	10.52	11.95	10.62	9.87	8.32	4.98	2.87	1.66

Unlike the previous table, which shows the possible draught by drainage alone, this table shows the combined effects of drainage, evaporation and vegetation. The average year probably represents the extent of depletion consistent with the best development of our vegetation. It begins with May and extends through the autumn, and, in southern New Jersey, through the year. The ordinary dry year is probably not far from the limit beyond which vegetation suffers badly, and the driest period represents extremely hurtful conditions, and which if continued would result in a change of the character of our vegetation.

The actual depth into the soil to which this depletion penetrates cannot well be ascertained. The depth to which the drainage extends is much greater than that to which actual dryness of the soil penetrates. The percentage of voids in sand amounts to about 25 per cent. of the whole mass, and closer soils have about 10 per cent. of voids, so that the average depletion will range from four to ten times the depletion measured by the depth of water extracted, or may be assumed to average about seven times. For an average year, therefore, in northern New Jersey it will extend from 9 to 24 inches, and for the driest year from 42 to 56 inches. Upon a given watershed the depletion will range from nothing along the stream lines to probably about twice the above amounts along the ridge line, consequently it is probable that the above depletion for the average year is quite sufficient to cause a drainage of 36 inches on the uplands, which we have seen to be necessary to perfect vegetation. In southern New Jersey a part of the depletion is from swamp-storage, but probably the ground-water is depleted to the extent of 10 inches in the driest time, or to a depth of from 24.5 inches in the average year to 70 inches in the driest year. It will be noticed that the ground-water is lowered for a much longer period in southern New Jersey than in the northern part, and it is not improbable that this bears some share in the well-known dryness of the winter and spring climate.

EFFECT OF FORESTS UPON STREAM-FLOW.

We have already called the reader's attention to the report upon forestry made by F. B. Hough to the Commissioner of Agriculture, in 1877, which embodies practically all that it is desirable to say as to the results of the ordinary experiments upon this subject.

DUNDEE DAM AND RACEWAY.

As we are able to approach it from a somewhat different standpoint, however, and, in view of the prevailing and commendable interest in the preservation of our forests, a brief summary of our findings in this connection may not be amiss.

We believe it will be helpful to the cause of forestry in the future if the effects of forests upon stream-flow are more carefully and accurately stated.

First, it is necessary to be careful in accepting too implicitly popular opinion upon the subject. We have heard everywhere throughout the State emphatic declarations that within the memory of the relators there had been a decided shrinkage in the volume of streams, and this is almost always attributed to deforestation. On the Raritan, the fact is cited that it was previously customary to freight goods by boat as far up as North Branch, and indeed, in 1736, members of the writer's own family conveyed their household goods by this means up the Raritan and up Green brook as far as the present city of Plainfield, this being then the most available means of transportation. It is claimed that this could not be done at present. It must be remembered that by the construction of the Delaware and Raritan canal, in 1833, very considerable changes were made in the regimen of the lower stream, and if it were not for these changes we can see nothing to prevent navigation of the river to a considerable extent at present, during a part of the year, by such boats as were then in use. The great improvement in methods of transportation, however, and consequent change of the point of view, make such a proposition now seem ridiculous. We use this as an illustration of a class of facts which are advanced to demonstrate the shrinkage of the Rancocas and other streams of the State which were once considerably used for shipping produce. We cannot regard such evidence as conclusive.

As to the claims of shrinkage in the volume of streams during the memory of persons now living, we must remember that if this has taken place it can hardly be charged to deforestation. The census returns show that since 1850 the improved land in the State has increased only 330,000 acres, or 7 per cent. of the whole land area, and this is confined to a few localities. It is perfectly safe to say that in northern New Jersey there has been practically no increase in cultivated land for a period of 50 years. Again, we have found that the large forested areas of the northern portion of the State consist mainly of a growth of from 35 to 45 years, and we are disposed to place the period of maximum deforestation at about 1850. This was brought about by the large demand for charcoal for the then numerous iron works of the State, and the method of cutting timber was to include everything in sight. We are told that at about this time large areas of the Highlands presented a perfectly bare appearance. In view of these facts we are compelled to conclude that if the alleged changes in the stream are a fact they cannot be due to deforestation, unless it may be in the case of the Delaware. A good foundation for this prevalent opinion that the volume of the streams averages less than formerly may be found in our diagram of rainfall, Plate I. If these persons contrast mentally the dry period which has prevailed since about 1875 with the wet period between 1855 and 1875, their opinion would be amply justified so far as the decreased flow of the streams is concerned, and the reason is apparent.

We have already shown, in our remarks upon the laws which governed evaporation, that there is nothing in our observations of stream-flow which indicates that forests or other vegetation have any marked effect upon the total annual evaporation from a water-shed. Indeed, if such a difference in this respect as is sometimes claimed actually existed, we should expect to find the prevalence of forests in regions where the rainfall was too light to support other vegetation. This does not appear to be the case, and indeed it would seem to be rather the reverse.

Again, we must not expect to be able to show any increase in the height of extreme floods from deforestation, for these are usually due to a peculiar combination of circumstances which are beyond the control of forests, and precisely the same thing is true as to the lowest flow. We shall not be able to show any decrease in this, but we may show that moderately-heavy floods are more prevalent, and periods of very low flow more frequent and longer extended.

It does not follow from the above that the beneficial effects of forests are to be depreciated. On the contrary, they can be and should be put upon grounds that are incontestable. Their effect in holding and preserving the soil upon slopes is very well known, and besides this they create a mass of humus and absorbent matter upon the surface which has an effect upon stream-flow, and the general evils resulting from deforestation are a matter of careful observation and record, so that too much stress cannot be laid upon the desirability of preserving a proper area of forests.

So far as they affect the flow of streams we consider their most valuable service to be that they equalize the flow, which they undoubtedly do to a marked extent. Something of this appears to be traceable in the difference between the ground-flow curve of the Sudbury, with about 14 per cent. of forest, and that of the Passaic, with about 44 per cent. The extremely low ground-flow of the Neshaminy, which is largely deforested, appears to be also in part due to the same cause. These curves are shown in Plate IV., page 82.

The study of these curves shows that in every case, almost, it is the water-shed on which is the largest proportion of forest which shows the largest flow from ground-water. Thus, the Sudbury curve falls below that of the Croton, and still more below that of the Passaic. The Neshaminy and Tohickon have the smallest amount of forest and the lowest curve of ground-flow. While we know that it is not entirely due to forests, it would seem to be indicated that they bear an important part in bringing about the result. Turning now to Plate VI., at page 126, and remembering that we should compare only streams having approximately the same-sized water-shed, we find of the Raritan and Passaic that the latter shows a much better-sustained flow for the latter part of a dry period. The same thing is true of all the other streams which are properly comparable, and the possibility that forests have an important bearing in this respect upon the flow of streams is strongly suggested. If we now turn to the table of flow from ground-water when rainfall equals evaporation, on page 340, we have a measure of the effect of such increased flow from ground-water. Compare, for instance, the Passaic and Raritan, and we see that although the total flow from ground-water on the Passaic is less than that upon the Raritan, after the fourth month the flow of the Passaic is considerably larger, averaging about 20 per cent. in excess of that of the Raritan. While the much larger flow of the coast streams is mainly due to other causes, it is still suggestive of the nature of the real benefits which result to streams from a prevalence of forests. As to the effect upon floods, this follows as a sequence of the increase in ground-flow. As an illustration, let us take the flow of the several classes of New Jersey streams during September, 1882, a month in which great floods prevailed all over the northern part of the State. If we assume the rainfall everywhere at this time to have been the same as that of Philadelphia, or 12.09 inches for the month of September, as we have done in the driest period of our several tables of flow, we have the following table:

RAINFALL AND FLOW-OFF IN FLOOD MONTH, SEPTEMBER, 1882.

	Rainfall, less Evaporation.	Flow-Off.
Kittatinny valley and Highlands	8.51	7.27
Passaic	8.04	5.69
Northern red sandstone	7.74	3.58
Raritan	7.74	4.73
Small red sandstone	7.74	5.75
Delaware above Trenton	8.51	6.90
Branches of Delaware, Trenton to Camden	7.47	2.32
" " Camden to Bridgeton	7.47	2.32
Coast streams, large ground-storage	7.47	1.32

The total flow-off for this month is seen to vary from 7.27 to 1.32 inches, whereas the excess of rainfall over evaporation ranges only from 8.51 to 7.47 inches. The great difference in the amount of water flowing off is due to the difference in the amount absorbed by the earth, which ranges from 1.24 inches in the Highlands and Kittatinny valley to 6.15 on the coast streams. All through this table it is seen that the flood-flow must vary in volume inversely with the capacity for ground-storage, consequently anything which tends to increase this capacity tends to decrease the volume of floods. The modifying action of forests upon such storage is certainly limited to within the range of conditions exhibited by the northern New Jersey streams. It happens at times, on all of these, that a heavy rainfall occurs when the ground-storage is full, and the result must be a flood. The maximum rate of flood-flow on these streams occurs with such exceptional conditions as these, or when there is a heavy fall of rain upon a large accumulation of snow or upon frozen grounds. It is for this reason that we have taken the position that we must not look for a decrease in this maximum rate of flow to be brought about by forests. The above showing indicates, nevertheless, that the average of floods will be reduced and the frequency of their occurrence materially decreased by forests.

There is, furthermore, little doubt that the very large storage-flow of the southern New Jersey streams is in part due to the forests, especially in the swamps. This effect is produced in part by the power for large absorption of water and slow parting therewith, which is peculiar to humus, as shown in the table previously quoted from Becquerel, and in part to the retention of water by absorbent mosses and by the inequalities of the surface which are characteristic of forests, and which hold the rainfall until it can take advantage of the facilities afforded for its percolation into the subsoil through the channels provided by the roots of the trees. We cannot better illustrate how beneficial this equalizing effect may be than by suggesting to the reader a comparison between the computed flow of the coast streams during the driest period, as shown by Tables Nos. 60 and 61, and the flow of the smaller red sandstone watersheds during the same period for the same rainfall, as shown by Table No. 56. He is likewise referred to the diagram of comparative flow of the Batsto and Neshaminy during the same period, shown in Plate X., page 292. The result of such increased capacity for natural storage and equalization of flow is a very much more serviceable stream for water-power or navigation, and the requirements of artificial storage in order to utilize a given amount of water per square mile are very much less, although the total run-off of the stream during the year is not necessarily any greater.

From a sanitary standpoint, it has been suggested that the most desirable condition of a water-shed is about that of our Highland country, with clearings near the streams to the extent of 20 or 25 per cent. of the whole area, which freely admit sunlight and air. This is probably preferable to a solidly-wooded district, especially if these clearings are kept in grass. It may be remarked that at present there does not appear to be any danger of further deforestation upon our water-sheds, unless it may be from fires in the southern portion of the State.

EFFECTS OF CULTIVATION UPON STREAM-FLOW.

These effects cannot be very marked upon the total quantity of water flowing in a stream for a given rainfall. This follows from our previous conclusions. No such effect is found in the recorded gaugings, any differences of flow there observed being more satisfactorily accounted for by temperature. We also found that the removal of the water held in the voids of the soil does not interfere with, but is beneficial to vegetation, which is best supplied from the water held by capillary attraction, and such capillary water can have but little effect upon stream-flow. It is highly probable, however, that the tilling of the soil greatly increases its absorbent capacity, and probably increases materially the total flow from ground-water. On the other hand, thorough drainage and underdrainage quicken the discharge of such waters, thus producing a large flow at the beginning of the draught upon ground-water but a decreased flow for the later months of a dry season, consequently the periods of extreme low flow are longer upon cultivated water-sheds. An instance and an excellent illustration of this fact may be seen in the ground-flow curve of the Raritan as compared with that of the Passaic in Pate VI., at page 126, also in the table of flow from ground-water, on page 340.

As between cultivated and barren water-sheds, therefore, the cultivated will show the steadiest conditions and the best-sustained dry-season flow, but as between cultivated and forested water-sheds the forested will produce the best results, the stored ground-water being more slowly fed out and evenly distributed over the dry season. It follows also that floods will be most severe upon barren areas, but as between cultivated and forested areas there will probably be no marked differences in this respect. It is readily seen that of all classes barren water-sheds are the most undesirable, consequently there follows the urgent necessity of preserving forests upon slopes and all areas which are not adapted to agriculture.

Cultivation undoubtedly, both from constant distribution of the soil and the use of fertilizers, as well as the attendant pollution from barnyards and the increased population, may render waters less pure and wholesome.

GEOLOGY OF THE STATE IN RELATION TO STREAM-FLOW.

The accompanying geological map will be of use in connection with these studies because the geological formations are the key to the character of the streams, as they are to the topography, climate and other physical characteristics of the State. As a rule, the water-sheds which lie upon the same geological formation will be found to have a strong resemblance, both in the character of the flow and in the chemical composition of the waters. We have followed these geological formations of necessity in grouping our streams. The Kittatinny valley and Highlands group corresponds exactly with the boundaries of these formations. So we have the Red Sandstone plain group; and the Trenton to Camden and Camden to Bridgeton group are mainly subdivisions of the Cretaceous or clay and marl region, while the coast streams coincide generally with the Tertiary. The first two divisions are crossed by the moraine line, and over all of the

country north of this there is much scattered drift, composed of boulder earth, sands and gravels, which sometimes cover the underlying rock to a depth of hundreds of feet. Glacial action has often stripped the decomposed rock and soil from the ridges and filled the valley with debris, and many of the lakes here are formed by drift dams which fill the valleys. The areas north of the moraine are invariably much more generally forested than those of the same formation south.

The Paleozoic formation consists largely of slate and limestone rocks, which are as a rule covered with a good soil, and the valley bottoms are usually fine grazing land. The upland clearings are devoted to general farming, the distribution of vegetation being generally about that shown in Table No. 19, page 38. The elevations in Kittatinny valley range from 400 to 1,000 feet, and on the mountain which runs parallel to the Delaware along the divide between that stream and the Paulinskill, from 1,200 to 1,800 feet. The valley has about 22 per cent. of its area in timber, and the mountain 60 per cent. The waters of this district, if we judge them by the analysis given for the Pequest, are rather hard. They are also more turbid than those of the Highlands.

The Archæan formation is co-extensive with the Highlands, which range from 500 to 1,500 feet in elevation, and consist of a number of parallel ridges and valleys. Northeast of the moraine they are well wooded, forest covering about 75 per cent. of the area, and ranging as high as 90 per cent. in some townships. Southwest of the moraine the average is not over 30 per cent. of forest, which is mainly on the slopes too steep for cultivation. This portion is well covered with soil and quite highly cultivated. The underlying rock is gneiss, with a little slate and limestone in some of the valleys.

The Red sandstone formation, or Triassic, is a rolling plain, the elevations ranging from 0 to 900 feet, but for the most part the country is below 300 feet. The underlying rock is mainly shallow, of an argillaceous character, which, in places, becomes a sandstone. It has a red color. Northeast of the moraine line this region is densely populated, and about 40 per cent. is in timber. There is less highly-cultivated land than would be supposed from its populous character. Southwest of the moraine, the country is of an agricultural character and highly cultivated, the average in forest being only 13 per cent., and for large areas in the valley of the Raritan not over 3 per cent.

The distribution of vegetation is well shown in Table No. 18, page 37. The stream-waters of this region are good when not artificially polluted, but they carry a large amount of red mud when slightly swollen.

The Cretaceous formation, or clay and marl region, is a level belt of country, the elevation rarely exceeding 200 feet. The portion northwest of a line drawn from Bordentown to Raritan bay, at a point about midway between Keyport and South Amboy, is nearly all clay, overlaid with sand and gravel, which reaches a considerable depth in the northeastern portion. From 40 to 60 per cent. of this is wooded. The remainder is made up of alternate strips of marl and sand and is the most fertile portion of the State. An average of about 8 per cent. of this is wooded, and the remainder is in a high state of cultivation. Because of this and the prevalence of marl and clay outcrops, the streams are, as a class, the least desirable for water-supply, and are frequently quite turbid. There are conspicuous exceptions to this rule, however, as portions of the district, being more sandy and gravelly, partake largely of the character of the Tertiary formation and furnish excellent water.

The Tertiary formation has been quite fully described under the heading of coast streams. It is a country of silicious sand and gravel soil, the sand being in some places much like that of the sea-shore. It is covered with a scanty growth of pine on the uplands and in the swamps by cedar, which is often dense, and with which the streams are nearly all bordered. The waters are very soft and pure, but usually have a brownish tinge.

The Geological Atlas, on a scale of one inch to the mile, showing the surface geology of the State in detail, which is now in preparation by this Survey, will give fuller and more accurate data of a kind which has a more direct bearing upon stream-flow, and will be valuable to those who wish to study these conditions more minutely.

A BRIEF SUMMARY OF STREAM-FLOW.

For the use of those who do not need to go more fully into the subject, but who wish to have conveniently at hand the leading facts regarding the streams of the State, the following summary may prove useful. We have endeavored to include in it the facts most commonly needed for preliminary or general estimates:

RAINFALL AND AMOUNT OF RAIN FLOWING OFF.

Average Year.

	Rain—Inches.	Flow-off—Inches.
Kittatinny valley and Highland streams	44.09	24.41
Delaware above Trenton	45.29	24.75
Passaic water-shed	45	21.30
Red sandstone streams	45.94	21.72
Branches of Delaware, Trenton to Camden	47.22	20.66
" " Camden to Bridgeton	45.88	19.61
Coast streams	49.10	21.88

Driest Calendar Year.

Kittatinny valley and Highland streams	31.63	16.82
Delaware above Trenton	31.63	17.43
Passaic water-shed	31.63	15.53
Red sandstone streams, Hackensack	31.63	17.68
" " " Raritan	31.63	16.25
" " " small streams	31.63	14.83
Branches of Delaware, Trenton to Camden	31.63	17.62
" " Camden to Bridgeton	31.63	17.62
Coast streams with moderate ground-flow	31.63	17.62
" " " large ground-flow	31.63	18.65

Driest Eighteen Consecutive Months.

Highlands and Kittatinny valley streams	51	21.06
Delaware above Trenton	51	21.24
Passaic water-shed	51	17.97
Red sandstone streams, Hackensack	51	18.26
" " " Raritan	51	17.03
" " " small streams	51	16
Branches of Delaware, Trenton to Camden	51	15.87
" " Camden to Bridgeton	51	15.87
Coast streams with moderate ground-flow	51	15.87
" " " large ground-flow	51	17.14

The average flow daily during the driest month on each of these streams, and the probable flow for the driest day when not held back in ponds, are as follows:

FLOW IN GALLONS DAILY FOR ONE SQUARE MILE OF WATER-SHED.

Class of Streams.	Average for Driest Month.	Driest Day.
Kittatinny valley and Highlands with ordinary water-sheds	81,000	81,000
" " " " " large ground-flow	140,000	110,000
Delaware above Trenton	127,000	110,000
Passaic	127,000	110,000
Red sandstone streams, Hackensack	123,000	122,000
" " " Raritan	84,000	84,000
" " " small streams	22,000	5,000
Branches of Delaware, Trenton to Camden	168,000	120,000
" " Camden to Bridgeton	168,000	120,000
Coast streams with moderate ground-flow	168,000	120,000
" " " large ground-flow	168,000	168,000

If we collect the surplus water of wet months in storage reservoirs and draw upon these during dry months, then we can draw from one square mile of water-shed the following average amounts of water daily during the driest periods:

GALLONS DAILY COLLECTIBLE WITH STORAGE FROM ONE SQUARE MILE.

Kittatinny valley and Highland streams	666,094
Delaware river above Trenton	666,094
Passaic river	666,094
Red sandstone streams	570,938
Branches of Delaware, Trenton to Camden	570,938
" " Camden to Bridgeton	476,090
Coast streams	570,938

WATER-POWER AVAILABLE FROM ONE HUNDRED SQUARE MILES OF WATER-SHED ON ONE FOOT FALL DURING AN AVERAGE OF NINE MONTHS IN EACH YEAR AND DURING THE DRIEST MONTH.

Class of Streams.	Theoretical Horse-Power. For Nine Months.	Driest Month.
Kittatinny valley and Highlands, ordinary streams	6.9	1.4
" " " " steadiest streams	6.8	2.5
Delaware above Trenton	7.9	2.2
Passaic river	4.5	2.2
Hackensack river	7.3	2.2
Raritan river	4.1	1.5
Poorest of red sandstone streams	2.8	.4
Streams from Trenton to Camden	7.5	3
Streams from Camden to Bridgeton	7	3
Coast streams, ordinary	10	3
" " poorest	7.7	3

APPENDIX I.

A LIST OF THE DEVELOPED WATER-POWERS OF NEW JERSEY.

WATER-POWERS.

From a Canvass Made in 1890-'91.

This list is intended to include every water-power in use in the State, and also such as have been recently used to an important extent, but are now unoccupied. The net horse-power is obtained usually from the capacity of the wheel-plant, taking account of its condition. When this was impracticable it was taken from estimates of the owners or managers, or from the amount of work being done in the mill. The gross horse-power was estimated from the net, and shows the amount of power needed to drive the plant. In estimating it the general efficiency of the wheel-plant, or in cases where the net power was taken from work performed, the efficiency of the whole of the machinery was considered. This gross horse-power, giving the amount of water actually needed to drive the mill, taken with what was learned as to the number of months in which full power could be used, furnishes an indication of the usual flow of the stream.

There are difficulties met with in making such a canvass as this, which render entire accuracy difficult to attain. It is believed that this is a fairly accurate presentation of the interest, however, as it stood at the date of making the canvass.

The power is divided among the several industries as shown in the table. Grist and flouring mills use 39.5 per cent. in northern, and 49 per cent. in southern New Jersey; 42 per cent. of the whole power of the State. The average power of these mills is 28.6. Saw, turning and other wood-working establishments use 10 per cent. north, and 23 per cent south, or 13 per cent. for the State. Their average power is 15.6 horse-power. The mills classed under fabrics and fibres use 14 per cent. of the power, having an average power of 74.6. Paper mills, being large users of power, are placed under a separate class from fabrics and fibres, to which they really belong.

They use 10.7 per cent., with an average of 118 horse-power each. Iron-working mills use 10 per cent., and average 65 horse-power. Miscellaneous manufacturers utilize 11 per cent., averaging 56.5 horse-power each and including a great variety of industries, among which may be mentioned the manufacture of photographic lenses, grinding of soapstone, driving of pumps for supplying water to cities, and of electric-light plants. Paterson, Trenton, New Brunswick, Passaic, Millville, Somerville and Raritan, Lakewood, Wenonah and Nutley have each a water-power pumping-plant for water-supply. Boonton and Lakewood have electric-light plants run by water-power.

Classifying the northern streams by entire water-sheds, we have:

	No. of mills.	Net horse-power.
Delaware above Trenton	186	6,658
Wallkill	25	598
Passaic	216	8,924
Hackensack	25	404
Elizabeth	2	36
Rahway	15	356
Raritan	171	5,993

The Passaic stands at the head of the streams, in both total horse-power and horse-power per square mile, the latter being 11.3. This refers to the streams as here grouped, however, for the Musconetcong, taken separately, shows 12.9 per square mile. Of the other Delaware streams, Flat brook shows 2.1, Paulinskill 5.4, and the Pequest 6.1 net horse-power per square mile. The Wallkill has 2.8 and the Raritan 5.4 per square mile. The southern streams should not be expected to show nearly so much power per square mile, as the fall is much less and the country more sparsely settled. Crosswicks creek shows 4.7; the Cohansey, 3.6; Metedeconk river, 3.5; Assanpink creek, 3.4; Maurice river, 2.8; Rancocas creek, 2.3; Great Egg Harbor, 1.4, and Mullica river, 1.0 horse-power per square mile. For the entire State, taking the land-surface at 7,514 square miles, the average is 4.11 net horse-power per square mile.

ESTIMATED VALUE OF UTILIZED WATER-POWER.

The total amount of power in the State is 30,870 net horse-power. If we assume an efficiency of 70 per cent., which is about what is obtained with good wheels, we shall have a gross horse-power of

44,100. In reality more power is required to run the above plants, as the average efficiency is below 70. Taking this power to be worth an average rental of $22.50 per horse-power per annum, or about two-thirds the rate at Paterson, Passaic or Trenton, we have a total rental of $992,250. Capitalizing this at 10 per cent. would give a value of $9,922,500 for the water-powers of the State. If we add to this the value of the buildings and machinery in the 903 mills using water-power, I do not think the most conservative estimate would make a total of less than $20,000,000 to represent the value of the water-power plants of the State.

In order to fully appreciate the importance of this interest, however, we must consider the great wealth which has been brought to us by the development of these powers. Paterson, now a city of 78,347 inhabitants, with large industrial interests, was created by and has grown up around the water-power of the Society for the Encouragement of Useful Manufactures. Trenton, with 57,458 inhabitants, and another of our most flourishing manufacturing centers, was only a village when the water-power was created, which formed the nucleus of its rapid growth in population and wealth. Passaic, with 13,028; Bridgeton, with 11,424; Millville, with 10,002 inhabitants; Lambertville, Boonton and several smaller towns, owe their being and industrial importance directly to this cause.

LARGE WATER-POWER PLANTS OF NEW JERSEY.

Stream.	Location.	Fall in feet.	Net H. P. in use.
Passaic	Paterson	66	1,760
Passaic	Passaic	22	1,235
Rockaway	Boonton	101	970
Delaware	Lambertville	9.5 to 18	747
South branch of Raritan	High Bridge	47	730
Maurice river	Millville	22	690
Delaware	Trenton	9 to 17	589
Musconetcong	Riegelsville	20	430
Musconetcong	Warren Paper Mills	48	360
Great Egg Harbor	Mays Landing	10	342
Musconetcong	Hughesville	27	340
Passaic	Little Falls	14	320
Pequannock	Butler	30	260
Rockaway	Old Boonton	30	260
Wading river	Harrisia	12	225

NUMBER OF MILLS AND NET HORSE-POWER BY WATER-SHEDS AND BY INDUSTRIES.

Streams of Northern New Jersey.

STREAM.	Grist and Flouring Mills.		Saw, Turning, Furniture and other Wood-Working.		Fabrics and Fibres, Woolen, Cotton, Silk, Felt, &c.		Paper.		Rolling Mills, Forges and other Iron Works. Machinery.		Miscellaneous Manufactures.		Total for Each Water-shed.	
	Number of Mills.	Net H. P.	Number of Mills.	Net H. P.	Number of Mills.	Net H. P.	Number of Mills.	Net H. P.	Number of Mills.	Net H. P.	Number of Mills.	Net H. P.	Number of Mills.	Net H. P.
Delaware, main stream and small branches	35	1,056	8	119	4	225	4	487	3	61	7	314	61	2,262
Flat Brook	4	105	2	32	....	....	....	....	....	....	....	....	6	137
Paulinskill	19	614	17	216	2	30	....	....	3	59	3	42	44	961
Pequest	22	735	11	205	....	....	....	....	1	25	....	....	34	965
Musconetcong	16	795	3	47	....	....	3	955	2	155	3	90	27	2,042
Pohatcong Creek	11	243	3	48	....	....	....	....	....	....	....	....	14	291
Wallkill and branches	15	387	6	107	....	....	1	47	1	37	2	20	25	598
Passaic, main stream and small branches	12	320	15	223	27	2,185	3	324	11	661	11	879	79	4,592
Saddle River	15	248	22	202	5	92	1	50	2	25	2	83	47	700
Ramapo	1	10	5	60	2	45	....	....	1	80	....	....	9	195
Wanaque	4	90	5	46	1	110	....	....	....	....	1	25	11	271
Pequannock	5	104	6	218	1	60	2	275	1	12	3	365	18	1,034
Rockaway	7	149	4	40	4	284	1	260	9	312	4	353	29	1,398
Whippany	9	247	7	75	1	70	4	276	2	66	....	....	23	734
Hackensack and branches	8	191	16	168	....	....	....	....	1	45	....	....	25	404
Elizabeth and branches	2	36	....	....	....	....	....	....	....	....	....	....	2	36
Rahway and branches	6	94	3	34	2	128	4	100	....	....	....	....	15	356
Raritan, main stream and small branches	12	346	1	10	2	205	1	25	....	....	5	426	21	1,012
South River	8	339	2	49	1	9	....	....	....	....	4	279	15	676
Millstone	19	532	2	22	1	18	....	....	....	....	....	....	22	572
North Branch	28	751	10	142	1	16	....	....	1	107	6	36	46	1,052
South Branch	50	1,678	12	216	1	12	....	....	4	775	....	....	67	2,681
Total for Northern New Jersey	308	9,070	160	2,279	55	3,489	24	2,799	42	2,620	51	2,912	640	22,969

NUMBER OF MILLS AND NET HORSE-POWER BY WATER-SHEDS AND BY INDUSTRIES—Cont.

Streams of Southern New Jersey.

STREAM.	Grist and Flouring Mills.		Saw, Turning, Furniture and other Wood-Working.		Fabrics and Fibres, Woolen, Cotton, Silk, Felt, &c.		Paper.		Rolling Mills, Forges and other Iron Works. Machinery.		Miscellaneous Manufactures.		Total for Each Water-shed.	
	Number of Mills.	Net H. P.	Number of Mills.	Net H. P.	Number of Mills.	Net H. P.	Number of Mills.	Net H. P.	Number of Mills.	Net H. P.	Number of Mills.	Net H. P.	Number of Mills.	Net H. P.
Streams entering Raritan Bay	2	55											2	55
Navesink River	6	191	2	61									8	252
Manasquan River	4	117	5	88									9	205
Metedeconk River	2	67	5	72							1	120	8	259
Toms River	3	73	8	157			1	58					12	288
Mullica River	5	69	7	134			2	375					14	578
Great Egg Harbor River	7	60	12	152	1	342	1	70					21	624
Small streams entering Atlantic Ocean	10	238	14	298									24	536
Maurice River	8	249	8	148	1	500			1	60	2	112	20	1,069
Cohansey Creek	8	225	3	50					1	100			12	375
Small Branches of Delaware Bay	8	155	5	75									13	230
Rancocas Creek	12	463	11	165					1	135	1	12	25	775
Crosswicks Creek	14	404	7	150	2	65					1	30	24	649
Assanpink Creek	5	127									2	180	7	307
Small branches of Delaware River, Trenton to Cohansey Creek	47	1,317	14	256					1	100	2	26	64	1,699
Total for Southern New Jersey	141	3,810	101	1,806	4	907	4	503	4	395	9	480	263	7,901
Total for the State	449	12,880	261	4,085	59	4,396	28	3,302	46	3,015	60	3,392	903	30,870

WATER-POWERS OF NORTHERN NEW JERSEY.

Flat Brook and Branches.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED.		REMARKS.
						Net.	Gross.	
Flat Brook	Flatbrookville	Sussex	Samuel Gariss	Grist and saw	12			Burned down.
“ “	Walpack township	“	Mrs. Charles Haney	Grist	6	30	50	
“ “	“ “	“	“ “ “	Saw	6	10	20	
“ “	Peters Valley	“	John Kean	Grist	7	17	23	
Big Flat Brook	Sandyston township	“	John D. Snook	Saw	16	22	31	
Branch at Tuttle's Corner	Tuttle's Corner	“	Samuel Smith	“	15			Not in use.
Little Flat Brook	Layton	“	John B. Rosenkrans	Grist	20	28	40	
“ “ “	Hainesville	“	Washington Lantz	Flouring	20	30	42	

Paulinskill and Branches.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED.		REMARKS.
						Net.	Gross.	
Paulinskill	Columbia	Warren	Heirs of Pace Love	Saw	13			Not in use.
“	Warrington	“	E. G. Bulgin	Grist	8	50	100	
“	Hainesburgh	“	G. C. Adams & Co.	“	9	75	110	
“	“	“	“ “ “	Saw	9	20	33	
“	Paulina	“	A. N. Snover	Grist	7½	30	50	
“	“	“	A. W. Snyder & Co.	Saw	7½	17	24	
“	“	“	A. J. Hill	Grist	9			Not in use.
“	Marksboro	“	George Wale	Photographic lenses	6	17	24	
“	“	“	W. H. Clarke	Grist	9	28	40	
“	“	“	“ “	Saw	9	28	40	
“	Hardwick township	“	John Vanstone	Sorghum	4½			Not in use.
“	“ “	“	Bert Wintermute	Saw	6½	12	20	
“	Stillwater	Sussex	H. Hopler	Grist	8	20	40	
“	“ township	“	James Butler	“	7	20	40	
“	Baleville	“	J. H. Northrup & Co	Turning	6	20	40	
“	“	“	A. J. Bale	Grist	7	20	29	
“	“	“	“ “	Carding	7	20	50	
“	Lower Lafayette	“	Coolver & Huston	Grist	20⅝	40	66	
“	“ “	“	“ “	Saw	8	10	20	
“	“ “	“	“ “	Foundry	12			Not in use.

WATER-POWERS OF NORTHERN NEW JERSEY—Continued.

Paulinskill and Branches—Continued.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED.		REMARKS.
						Net.	Gross.	
Paulinskill	Lafayette	Sussex	Coolver & Huston	Foundry	11	....	....	Not in use.
"	"	"	O. P. Armstrong	Grist	27	30	50	
Yard's Creek	Hainsburgh	Warren	Mary Pierce	Carding	13	10	20	
Branch at Kalarama	Kalarama	"	Isaac D. Lanterman	Saw	18	7	11	
" " "	"	"	John Painter	Grist	32	24	34	
Jacksonburg Creek	Jacksonburg	"	Mrs. Isaac F. Reed	Distillery	10	10	25	
" "	"	"	Samuel McConachy	Grist	18	15	25	
" "	"	"	J. M. Place	Saw	16	39	56	
Blair's Creek	Blairstown	"	John I. Blair	Grist	20	30	42	
" "	Hardwick Centre	"	John Voss	Saw	12	10	20	
" "	" township	"	Oman McGraft	"	....	8	16	
" "	"	"	Clark Bird	Feed and saw	20	60	86	
Trout Brook	Middleville	Sussex	Casper Losey	Saw	13	10	20	
" "	Stillwater township	"	Betsy Wintermute	Foundry	16	15	21	
" "	" "	"	" "	Saw	16	15	30	
Branch at Swartswood Lake	Swartswood Lake	"	John W. Kean	Grist	17	30	42	
" " " "	Stillwater township	"	C. T. Unangst	Grist and saw	35	20	40	
" " " "	" "	"	E. S. Decker	Tannery	18	15	30	
" " Fredon	Emmons Station	"	Richard Vanstone	Saw	18	10	20	
" " "	Fredon	"	William Smith & Bro	Grist	50	21	30	
" " Branchville	Branchville	"	V. H. Cressman	Flouring	22	40	57	
" " "	"	"	William Bell	Woolen	13	....	....	Not in use.
" " "	"	"	V. H. Cressman	Feed	24	41	58	
" " "	"	"	William Space	Woolen	50	....	....	Not in use.
" " "	"	"	William McDonalds	Feed and saw	18	20	33	
" " "	Mount Pisgah	"	William Bell	Saw	14	....	....	Not in use.
" " "	" "	"	" "	Forge	18	30	5	" "
" " "	" "	"	E. A. Ely	Machine shop	12	14	23	
" " "	" "	"	James Perry	Bark	14	10	17	
" " "	" "	"	William Bell, in trust	Lumber	20	....	....	Not in use.

WATER-POWERS OF NORTHERN NEW JERSEY—Continued.

Pequest River and Branches.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED.		REMARKS.
						Net.	Gross.	
Pequest	Belvidere	Warren	A. B. Searles	Flouring	17½	128	170	
"	"	"	G. K. & A. McMurtry	Saw	17½	45	60	
"	"	"	Ira B. Keener	Flouring	7	26	37	
"	"	"	Uhler & Lake	Furniture	7	35	50	
"	"	"	E. Van Uxem	Spokes	18	16	22	
"	"	"	Geo. K. & A. McMurtry	Flouring	18	104	150	
"	"	"	Belvidere Agricultural Co.	Agricultural machinery	18	25	36	
"	Bridgeville	"	Mrs. William Mackey	Grist	6	30	60	
"	Butzville	"	David Anderson.	"	9	33	44	
"	Townsbury	"	Heirs of Andrew Ketcham	Saw	10	10	25	
"	"	"	J. B. Smith	Feed	12	25	50	
"	"	"	John Green	Grist	12	25	50	
"	"	"	" "	Saw	12	15	30	
"	Tranquility	Sussex	Heirs of E. V. Kenedy	Flouring	5	25	37	
"	Huntsville	"	Geo. V. Northrup	Saw	10	15	21	
"	"	"	" " "	Grist	12	30	42	
"	Springdale	"	Seymour Stickles	"	6	20	50	
Beaver Brook	Sarepta	Warren	William Hutchinson					Not in use.
" "	"	"	John R. Buttz	Grist	8	10	15	
" "	"	"	Charles Bartow	"		24	48	
" "	Hope	"	John Sweazy	"	25	48	70	
Honey Run	Sweazy's Mill	"	" "	"		10	15	
Glover's Pond Outlet	Glover's Pond	"	—— Vasbinder	Saw	20	10	15	
Trout Brook	Hope	"	Levi J. Howell	Grist		12	24	
Green's Pond Branch	" township	"	John Parks					Not in use.
" " "	" "	"	Smith Hilderbrant	Cider	9	10	20	
" " "	" "	"	" "	Saw	12			
Furnace Brook	Oxford Furnace	"	Oxford Iron and Nail Co.	Flouring	28	36	72	
Branch at Vienna	Vienna	"	Charles Barker	"	36	37	53	
" " Petersburg	Petersburg	"	Robert Ayres					Not in use.
" " Warrenville	Warrenville	"	Lackawanna Iron and Coal Co.	Saw	20			" "
" " Johnsonburg	Johnsonburg	"	Elridge Harden	Grist		15	30	
" " Hunt's Pond	Huntsburg	Sussex	George Current	Saw	18	19	38	
" " " "	"	"	Theo. F. Hunt	Grist	30	22	31	

WATER-POWERS OF NORTHERN NEW JERSEY—Continued.

Pequest River and Branches—Continued.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED.		REMARKS.
						Net.	Gross.	
Branch at Alamuche	Alamuche	Warren	Rule H. Drake.	Saw	20	21	35	
" " "	"	"	Morris Haggerty	Grist	28	24	40	
" " "	"	"	Joseph Ayres	Saw	26	10	25	
" " "	"	"	Rutherford Stuyvesant	Grist	30	36	72	Not in use.
" " Andover.	Andover	Sussex	Heirs of John Seward Wills.	Flouring	28	15	25	

Pohatcong Creek and Branches.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	Net.	Gross.	REMARKS.
Pohatcong	Carpenterville	Warren	Isaac T. Riegel	Saw	9	25	36	
"	Springtown	"	Nathan Druckenmiller	Grist	7	12	30	
"	"	"	Thomas Paullus	"	8	12	25	
"	"	"	P. W. Skinner & Bro.	Flouring	8	24	40	
"	Greenwich township	"	John Kenedy	Grist	10	15	37	
"	" "	"	—— Hulsizer.	"	10	25	37	
"	Franklin township	"	Levi Cressman	Flouring	7½	17	24	
"	Pleasant Valley	"	New York Life Ins. Co.	Feed	11	24	60	
"	Washington	"	John Neilson	Grist	8	15	25	
"	Karrville.	"	William Larrison	Flouring	11	24	34	
"	"	"	William Karr	Wheelwright	6½	8	16	
"	"	"	William Ketcham	Saw	18	15	30	
Hihichehockhi	Stewartville	"	Jacob Shillinger.	Flouring	23	30	43	
Brass Castle Creek	Brass Castle.	"	Assign of James Lomerson	Grist.	60	45	56	
" " "	Washington township	"	John Smith	Saw	11	....	....	Not in use.

Musconetcong River and Branches.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	Net.	Gross.	REMARKS.
Musconetcong	Riegelsville	Warren	John L, Riegel & Son	Grist	20	175	250	
"	"	"	" " "	Paper	20	255	364	
"	Finesville	Hunterdon	Taylor, Stiles & Co.	Machine knives	6	75	107	

WATER-POWERS OF NORTHERN NEW JERSEY—Continued.

Musconetcong River and Branches—Continued.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED.		REMARKS.
						Net.	Gross.	
Musconetcong	Finesville	Warren	I. A. Jacoby	Grist	6½	48	70	
"	"	"	" "		9			Not in use.
"	Hughesville	Hunterdon	Warren Manufacturing Co.	Paper	27	340	487	
"	Warren Paper Mills	"	" " "	"	48	360	514	
"	Bloomsbury	Warren	T. G. Hoffman	Foundry facings	9½ }	80	114	
"	"	Hunterdon	" "	Grist	9½ }	44	62	
"	Asbury	Warren	J. C. Reed and others	"	5½	36	60	
"	New Hampton	"	S. S. Cramer	"	5	30	42	
"	" "	Hunterdon	Martin Wyckoff	"	7	50	70	
"	Changewater	Warren	Bowers Snuff and Tobacco Co.	Snuff	9	35	50	
"	Point Mills	Hunterdon	J. D. Pidcock	Grist	9	25	50	
"	Penville	"	Peter Lance	"	8	50	70	
"	Stephensburg	Morris	John P. Sharp	"	8½	55	90	
"	Beattystown	Warren	White & Simanton	"	7	30	60	
"	Lower Hackettstown	"	Zephaniah Hoffman	"	8	36	72	
"	Hackettstown	"	Prost & Co.	"	5	36	60	
"	"	"	Lewis J. Youngblood	"	9½	50	80	
"	Upper Hackettstown	"	J. C. Welsh	"	9	36	60	
"	Near Saxton Falls	Morris	Archer Stevens' Sons	Saw	8	12	20	
"	Waterloo	Sussex	Smith Bros.	Grist	18 }	36	60	
"	"	"	" "	Plaster	18 }	40	80	
"	Old Andover	"	Matilda Van Doren					Not in use.
"	Stanhope	"	Musconetcong Iron Co.					" "
"	Lake Hopatcong	"	Morris Canal					" "
Branch north of Port Murray.	Mansfield township	Warren	H. S. Beatty	Grist	22	18		
" at Hackettstown	Hackettstown	"	James Boyd	Tannery	24	15	37	Not in use.
" " "	"	"	Christopher Morton	"	10	5	10	
" near Drakesville	Drakesville	Morris	Jonathan Coleman	Saw	15			Not in use.
" south of Stanhope	Stanhope	"	Heirs of John Seward Wills	"	22	15	30	
" " " "	"	"	" " " "	"				Not in use.
" at Waterloo	Waterloo	Sussex	John French	"	50	20	40	
Lubber's Run	Lockwood	"	Pope & Appleton	Forge				Not in use.

WATER-POWERS OF NORTHERN NEW JERSEY—Continued.

Musconetcong River and Branches—Continued.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED. Net.	H. P. UTILIZED. Gross.	REMARKS.
Lubber's Run	Roseville	Sussex	Robert L. Byerley	Forge				Not in use.
" "	Columbia	"	W. W. & L. F. Sutton	"				" "
" "	Near Columbia	"	Watson McPeek.	Saw				" "
" "	Sparta township	"	Lance Goble, Agt	"	20			" "

Delaware River and Small Branches.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED. Net.	H. P. UTILIZED. Gross.	REMARKS.
Branch at Montague	Montague	Sussex	Jacob C. Hornbeck	Grist	22	12	24	
Vancampen's Brook	Calno	Warren	John Zimmerman	Saw	18	10	20	
" "	Mill Brook	"	Heirs of Bartley Fuller	Grist	22	19	31	
" "	Walpack township	Sussex	David R. Hull	Saw	15	12	24	
Pophandusing Branch	Oxford Church	Warren	John C. Prall	Grist	24	30	60	
" "	" "	"	George Keiser	Tannery	16	10	25	
Buckhorn Creek	Hutchinson's	"	Samuel A. Depew	Saw	12			Not in use.
" "	"	"	" " "	"	20			" "
" "	Harmony township	"	Mrs. Archibald Davis					" "
" "	Roxburgh	"	Isaac Young	Foundry	8	15	20	
" "	"	"	R. M. Bowlby	Grist	45	36	60	
Lopatcong Creek	Phillipsburg	"	W. D. Hagerty	Saw	20	20	30	
" "	"	"	P. W. Skinner & Bro.	Flouring	14	24	34	
" "	"	"	F. G. Warne	Soapstone	18	12	18	
" "	Lopatcong	"	S. C. Purcell	Flouring	8	12	30	
" "	" township	"	John Holden	Grist	20	12	30	Not in use.
" "	Lower Harmony	"	" "	"	22	47	78	
" "	" "	"	William Vanatta	"	9	24	60	
" "	" "	"	Elijah Allen	"	18	12	24	
Branch at Carpenterville	Carpenterville	"	John Reese	"	10			Burned.
Alexsocken Creek	Mount Airy	Hunterdon.	Annie Blackwell	"	11	12	30	
Wickecheoke Creek	Locktown	"	Robert Holcomb	"	15	12	24	
" "	Sergeantsville	"	R. G. Johnson	"	25	12	24	
Lockatong Creek	Delaware township	"	Mahlon Strumpel	Grist and saw	24	10	17	
" "	Idell	"	Newbury Hagar	Grist	17	16	32	
" "	"	"	Henry Cook	"	21½	48	80	

WATER-POWERS OF NORTHERN NEW JERSEY—Continued.

Delaware River and Small Branches—Continued.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED.		REMARKS.
						Net.	Gross.	
Nishisakawick Creek	Frenchtown	Hunterdon	D. R. Worman	Flouring	20	24	34	
" "	"	"	" "	Grist and bone	24	15	25	
" "	Everittstown	"	Joseph Huff	Grist	24	36	60	
" "	"	"	Joseph Wilson	"	20	....	....	Not in use.
Harihokake Creek	Frenchtown	"	E. R. Case	Saw	....	....	....	
" "	Mount Pleasant	"	Daniel Johnson	Grist	29	27	40	
" "	" "	"	Rev. Joseph Manning	Saw	14	10	25	
Hakihokake Creek	Milford	"	W. & E. T. Thomas	Flouring	30	84	120	
" "	"	"	" " "	Grist	12	36	50	
" "	Little York	"	J. M Duckworth	"	30	36	60	
" "	" "	"	S. V. Eckel	"	33	35	50	
" "	" "	"	Samuel Kemenhower	Saw	23	12	30	
Spring Mill Branch of Hakihokake	Spring Mills	"	Jacob R. Anderson	Grist	27	25	50	
Delaware & Raritan Canal Feeder	Prallsville	"	Joseph Smith & Co	Flouring	8½	40	57	
Delaware & Raritan Canal Feeder	Lambertville	"	New Jersey Rubber Co	Rubber	15	....	....	Not in use.
Delaware & Raritan Canal Feeder	"	"	" " " "	"	15	100	140	
Delaware & Raritan Canal Feeder	"	"	Caroline Ely	Grist	19	45	64	
Delaware & Raritan Canal Feeder	"	"	F. F. Lear	Flouring	18	60	86	
Delaware & Raritan Canal Feeder	"	"	" "	Saw	18	15	25	
Delaware & Raritan Canal Feeder	"	"	Lambertville Paper Co	Paper	14	96	137	
Lambertville Water-Power Company	"	"	M. Sheppard	Twine	9½	40	80	
Lambertville Water-Power Company	"	"	William Mann Paper Co	Paper	9½	218	310	
Lambertville Water-Power Company	"	"	O'Brien Brothers & Co	"	9½	79	112	
Lambertville Water-Power Company	"	"	James C. Weeden	"	9½	94	134	

WATER-POWERS OF NORTHERN NEW JERSEY—Continued.

Delaware River and Small Branches—Continued.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED.		REMARKS.
						Net.	Gross.	
Delaware & Raritan Canal Feeder	Titusville	Mercer	George Agnew	Flouring	26	30	42	
Delaware & Raritan Canal Feeder	"	"	" "	Rubber	26	75	107	
Delaware & Raritan Canal Feeder	Somerset Junction	"	John Howell Borrough's Est.	Grist	18 28	24	34	
Trenton Water-Power Co.'s Raceway	Trenton	"	City Water Works	Pumping	9	20	27	
Trenton Water-Power Co.'s Raceway	"	"	Wm. Kennedy	Sawing and planing	12	40	55	
Trenton Water-Power Co.'s Raceway	"	"	B. W. Titus' Sons	Cotton and woolen.	12	25	33	
Trenton Water-Power Co.'s Raceway	"	"	Golding & Sons Co.	Potters' material	14	97	121	
Trenton Water-Power Co.'s Raceway	"	"	A. Thompson & Co.	Flouring	12	19	24	
Trenton Water-Power Co.'s Raceway	"	"	Nelson Thompson	"	12	12	16	
Trenton Water-Power Co.'s Raceway	"	"	Chas. W. Howell	"	13	80	120	
Trenton Water-Power Co.'s Raceway	"	"	S. Zigenfuss & Co.	"	12	70	88	
Trenton Water-Power Co.'s Raceway	"	"	Fisher & Norris	Iron works	14	6	10	
Trenton Water-Power Co.'s Raceway	"	"	Phœnix Iron Works	Machinery	14	40	65	
Trenton Water-Power Co.'s Raceway	"	"	Samuel K. Wilson	Woolen and worsted	12 17	100	135	Partly from Assanpink creek.
Trenton Water-Power Co.'s Raceway	"	"	William Walton	Flouring	17	20	27	
Trenton Water-Power Co.'s Raceway	"	"	Saxony Woolen Mills	Woolen	11	60	75	

WATER-POWERS OF NORTHERN NEW JERSEY—Continued.

Wallkill River and Branches.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL	H. P. UTILIZED.		REMARKS.
						Net.	Gross.	
Wallkill	Hamburg	Sussex	Glenn Estate	Forge				Not in use.
"	"	"	W. H. Ingersoll	Flouring	21½	75	107	
"	"	"	" "	Plaster	21½			
"	"	"	Augustus Cochran	Paper	24	47	78	Not in use.
"	"	"	W. H. Ingersoll	Saw	24			
"	Lehigh Junction	"	Franklin Iron Co	Forge				" "
"	Franklin Furnace	"	" "	Furnace				" "
"	Sparta	"	James L. Decker	Grist	18	19	31	
"	"	"	" "	Distillery	11	5	10	
"	"	"	James F. Titman	Flouring	21	36	51	
"	"	"	Dr. Andrus	Grist	25			Not in use.
Branch at Decker Pond	Vernon township	"	Henry L. Sammis	Saw	40	15	30	
" " " "	" "	"	" "					Not in use.
" " " "	" "	"	Thomas L. Babcock	Saw	16	12	24	
Papakating Creek	Frankford township	"	Daniel Wyker	"	12	8	20	
Clove River	Deckertown	"	R. J. Quince	Grist	16	24	40	
" "	North Deckertown	"	Albert Fuller	"	12	25	41	
" "	" "	"	William T. Wright	Lumber	22	20	33	
" "	Clove	"	William Titsworth	Saw				Not in use.
" "	Wantage township	"	John Decker & Mary Decker	Grist	24	24	40	
" "	" "	"	Dr. Charles Cooper	"	35	24	48	
" "	Coleville	"	Theodore C. Marthis	"	16½	20	32	
" "	"	"	Edward Baker's Estate	Spokes	16½	10	25	Not in use.
" "	"	"	J. E. Post	Saw	14			
West Branch of Papakating	Woodbourne	"	Philip Elston	Grist	40			" "
" " " "	Plumbsock	"	Nancy Compton and Emma Stelle	"	20	24	60	" "
" " " "	"	"	John Smith	Saw	18	32	52	
Branch at Wykertown	Wykertown	"	Samuel J. Corsen	Grist	40			Not in use.
Beaver Run	Wantage township	"	James Cox	"	16	12	24	
" "	" "	"	Benj. K. Jones	Foundry	24	37	60	
Branch at Hardystonville	Hardystonville	"	Milton I. Southard	Grist	20	36	60	
" near Ogdensburg	Ogdensburg	"	Augustus Tallman	Feed	18	10	25	
" at Lake Grinnell	Monroe Corners	"	Mrs. Susan Kemble	Grist	8	15	37	
" " " "	" "	"	J. C. Wilson	"	12	21	35	
Pochuck	Wawayanda	"	Victor H. Wilder	"	18			Not in use.

WATER-POWERS OF NORTHERN NEW JERSEY—Continued.

Wallkill River and Branches—Continued.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED.		REMARKS.
						Net.	Gross.	
Pochuck	Wawayanda	Sussex	Victor H. Wilder	Cheese-box factory.	10			Not in use.
"	"	"	" " "	Saw	18			" "
"	"	"	" " "	Furnace	35			" "
"	"	"	" " "	Creamery	8			" "
"	Vernon township	"	Martin Thaddock	Saw				" "
Branch at Glenwood	Glenwood	"	Daniel Bailey	Flouring	28	25	36	
" " "	"	"	Norman McKirk	Saw	15	10	25	
" " Vernon	Vernon	"	Joseph Burroughs	"				Not in use.
" " "	"	"	S. E. Wood	Feed	18	12	24	

Passaic River and Branches.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED.		REMARKS.
						Net.	Gross.	
Second River	Belleville	Essex	De Witt Wire Cloth Co.	Wire cloth	11	40	80	
" "	"	"						Not in use.
" "	"	"	Hendricks Bros.		12			" "
" "	"	"	" "		20			" "
" "	"	"	" "	Copper	19	100	200	
" "	"	"	National Print Works	Print works	18	25	36	
" "	Bloomfield	"	James Moffet	Brass rolling mills	20	25	40	
" "	"	"	Wheeler Bros.		12			Not in use.
Silver Lake Branch of Second River	Silver Lake	"	Thos. A. Edison	Grist	14			" "
Yantecaw	Delawanna	Passaic	J. & R. Kingland	Paper	22 15			" "
"	Nutley	"	" "	"	17	65	90	
"	"	Essex	Nutley Water Co.	Water works	8	10	14	
"	Franklin	"	——— Hilton	Woolen	6	40	80	
"	"	"	Underhill Mfg. Co.	Woolen underwear	12	37	61	
"	Bloomfield	"	E. H. Davey	Trunks and binders' boards	11	45	75	
"	"	"	Thomas Oakes & Co.	Woolen	16	38	54	
"	"	"	A. T. & Joseph Morris	Grist	12			Not in use.

WATER-POWERS OF NORTHERN NEW JERSEY—Continued.

Passaic River and Branches—Continued.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED.		REMARKS.
						Net.	Gross.	
Yantecaw	Bloomfield	Essex	Estate of Albert Moore	Saw	10	15	30	
Passaic	Passaic	Passaic	Dundee Water-Power and Land Co.	Miscellaneous	22	1,235	1,764	
Weasel Brook	Clifton	"	Richard A. Westervelt	Grist	15	....	....	
" "	Athenia	"	A. R. Post & Co	Saw	12	12	24	
Saddle River	Garfield	Bergen	—— Zabriskie	Cotton	5	....	....	Not in use.
" "	"	"	C. R. Van Dusen	Grist	6½	42	70	
" "	Lodi	"	Byrne Bros. & Co	Bleaching and dyeing	7½	....	....	
" "	Rochelle Park	"	D. Romaine	Rubber shoddy	6	58	71	
" "	Arcola	"	Dunlap & Co	Blankets	4	10	25	
" "	Midland township	"	J. Henry Blauvelt	Grist	7	11	18	
" "	" "	"	" "	Saw	7	10	20	
" "	Paramus "	"	Abram F. Z. Demarest	Grist	6½	12	30	
" "	" "	"	John D. Berdan	"	12	25	41	
" "	" "	"	" "	Saw	12	15	25	
" "	Orvil "	"	Thomas Eckerson	"	6	12	24	
" "	" "	"	" "	Cider and saw	6	5	10	
" "	" "	"	D. A. Blauvelt	Grist	8	15	37	
" "	" "	"	O J. Victor	....	7	....	....	Not in use.
" "	Saddle River	"	Abram Dates	Grist	6	10	25	" "
" "	" "	"	William W. Packer	Saw	7	10	25	
" "	" "	"	" "	Foundry	6	15	30	
" "	North Saddle River	"	J. Raymond Ackonback	Grist	4	20	50	
" "	" " "	"	Dr. O. Blyneth	Woolen	7½	20	33	
" "	" " "	"	W. J. C. Ward	Mechanics' tools	8	10	20	
" "	Orvil township	"	John E. Hopper	Saw	8	8	16	
" "	" "	"	Abram C. Hopper	"	8	15	25	
West Branch Saddle River	" "	"	Mary Halstead and Geo. De Baum	....	....	....	....	Not in use.
" " " "	" "	"	Henry P. Post	Grist	9½	12	24	
" " " "	" "	"	" "	Saw	9½	10	25	
" " " "	" "	"	Martin Tice	Feed and saw	8½	10	25	
East " " "	" "	"	G. J. Hopper	Saw	11	10	25	
Hohokus Creek	Undercliff	"	Abram J. Zabriskie	Saw and silk	6	15	30	

WATER-POWERS OF NORTHERN NEW JERSEY—Continued.

Passaic River and Branches—Continued.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED.		REMARKS.
						Net.	Gross.	
Hohokus Creek	Undercliff	Bergen	Estate of John R. Terhune	Rubber	14	25	42	
" "	"	"	" " "	Saw	13½	12	24	
" "	"	"	" " "	Turning	13½	10	20	
" "	"	"	McCafferty & Buckley		30	80	110	Not in use.
" "	Hohokus	"	W. D. Rosenkrantz, Agent	Cotton yarn	40	50	70	
" "	Waldrick	"	M. D. White	Saw and bark	18	18	26	
" "	"	"	Martin Margoff	Cotton	10	12	17	
" "	"	"	Charles White	Paper	13	50	70	
" "	Allendale	"	Richard Christopher	Grist	10	13	21	
" "	"	"	" "	Saw	10	8	13	
" "	"	"	A. A. Lydecker	Flouring	10	20	30	
" "	"	"	Jacob J Smith	Saw	8	10	20	
" "	North Wyckoff	"	John Gardiner					Not in use.
" "	" "	"	G. G. Ackerman	Flouring	9	20	30	
" "	" "	"	John W. Pulis	Grist and saw	11⅓	10	17	
" "	" "	"	John Haubner	Tannery	20			Not in use.
" "	Camp Gaw	"	J. H. Sturr	Grist	13	12	20	
" "	" "	"	" "	Saw	12	12	20	
Branch at Ramseys	Ramseys	"	Abner Benedict	Grist and bark	10	6	17	
" " "	Allendale	"	Charles Christopher	Saw	12	10	20	
" " Wyckoff	Wyckoff	"	P. S. Pulis	Saw and cider	4	4	10	
" " Saddle River	Saddle River	"	Thomas Van Buskirk	Saw	15	18	36	
" " Hawthorn	Hawthorn	"	Alyea Bros.	Grist	13	20	33	
Goffel Creek	"	Passaic		Dyeing	18			
" "	Van Winkle	"	S. P. Van Winkle	Grist	12	20	50	
" "	" "	"	" " "	Cider	10	4	10	
" "	" "	"	Joel M. Johnson		11			Not in use.
" "	Midland Park	Bergen	D. Baldwin	Cotton	16	12	20	
" "	" "	"	Metropolitan Bank of New York	"	24	12	20	
" "	" "	"	G. Morrough's Sons	Woolen	30	23	32	
" "	Wortendyke	"	Metropolitan Bank of New York	Silk	14	12	17	
" "	Wyckoff	"						Not in use.
Branch at Van Winkle	Van Winkle	Passaic	Maria Van Blarcom	Saw	16	10	20	
" " " "	" "	"	Preston Stevenson	"	22			Not in use.

WATER-POWERS OF NORTHERN NEW JERSEY—Continued.

Passaic River and Branches—Continued.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED.		REMARKS.
						Net.	Gross.	
Branch at Van Winkle	Midland Park	Bergen	Isaac G. Snyder	Paint	16	8	13	
Passaic	Paterson	"	Society for the Establishment of Useful Manufactures	Miscellaneous	66	1,760	2,350	
Haledon Creek	Haledon	Passaic	Henry L. Butler	Carpets	12	10	20	
Peckman's Brook	Jackson Park	"	James Edge	Bolts and nuts	6	8	13	
" "	" "	"	Estate of George Jackson	Scouring	10	20	30	
" "	Little Falls	"	S. Sindle	Grist	19	20	33	
" "	" "	"	" "	Felt	19	20	33	
" "	" "	"	James Van Ness	Dyeing	18	40	67	
" "	Cedar Grove	Essex	F. J. Marley	Saw	18	10	14	
" "	" "	"	" "	Hubs	18	12	17	
" "	" "	"	Elias Van Ness		7			Not in use.
" "	" "	"	Anthony Bowden	Cotton	16	12	20	
" "	" "	"	Andrew J. Wood	Woolen	11			Not in use.
" "	" "	"	J. J. Thatcher	Bronze powder	36	30	42	
" "	Verona	"	American Bronze-Powder Co.	" "	13	15	30	
" "	"	"	Montclair Syndicate	Saw	18	20	50	
Passaic	Little Falls	Passaic	Beattie Manufacturing Co.	Carpets	14	320	440	
"	Chatham	Morris	Geo. T. Parrot	Flouring	10	42	60	
"	"	Union	John P. Edwards	Machine	8	50	80	
"	"	"	" "	Paper	8			Not in use.
"	Stanley	Morris	Mrs. William Bonnell	Grist	8	40	80	
"	"	"	Armour Brothers	Paper	$7\frac{1}{2}$	52	75	
"	Millington	Somerset	William Leeson	Grist	$6\frac{1}{3}$	24	40	
"	Logansville	"	Richard Irwin's Estate	Saw	$6\frac{5}{12}$	12	24	
"	Franklin	"	F. Van Doren	Flouring	20	40	57	
"	"	"	Edna McMurtry	Saw	13	10	25	
"	Washington	Morris	William Little	Turning	16	62	90	
"	"	"	Abram Brockoven	Saw	10	20	40	
Green Brook	Caldwell township	Essex	Barney Cook and Henry Francisco	Cider	10	8	16	
" "	" "	"	Thomas C. Sindle	Grist	29	30	42	
" "	" "	"	" "	Saw	29	15	21	
" "	" "	"	O. Dorson	Grist	25			Not in use.
" "	" "	"	Sindle & Anderson	Turning	25	15	21	

WATER-POWERS OF NORTHERN NEW JERSEY—Continued.

Passaic River and Branches—Continued.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL	H. P. UTILIZED. Net.	H. P. UTILIZED. Gross.	REMARKS.
Green Brook	Caldwell township	Essex	O. Dorson	Saw	12	....	....	Not in use.
Ramapo River	Pompton	Passaic	Pompton Steel and Iron Co.	Steel & iron works.	20	80	160	
" "	Oakland	Bergen	Samuel B. Demarest	Silk	4½	20	30	
" "	"	"	" "	Saw	4½	12	20	
Franklin Lake Stream	"	"	James H. Van Blarcom	"	10	30	60	
" " "	"	"	Rev. Eugene Dikovich	"	10	....	....	Not in use.
" " "	Crystal Lake	"	H. M. Ranson	"	11	....	....	" "
" " "	" "	"	J. B. Ewing	Silk	21½	25	37	
" " "	Franklin Lake	"	Daniel Yeomans	Feed and saw	6 }	10	20	
" " "	" "	"	" "	Turning	6 }	10	20	
Branch at Mahwah	Mahwah	"	Winter & Bro	Saw	6	....	....	Not in use.
" " "	"	"	Henry Wanamaker	"	6	8	16	
Wanaque River	Pompton	Passaic	H. J. Smith	Silk	15	110	157	
" "	"	"	" "	Electrical fuse	9	25	36	
" "	Wanaque	"	Edward J. Skerrett	Turning	4	12	24	
" "	"	"	Peter J. Brown	Grist	7	24	48	
" "	Midvale	"	Cooper & Hewitt	Old forge site	15	....	....	Not in use.
" "	"	"	John Taylor Johnson	" " "	9	....	....	" "
" "	Monks	"	Daniel A. Wheeler	Saw and feed	12	28	40	
" "	"	"	Cooper & Hewitt	Old saw-mill site	8	....	....	Not in use.
" "	Hewitt	"	" "	Furnace	32½	....	....	" "
West Brook	Midvale	"	Albert Albeglse	Saw	10	8	13	
Ringwood Creek	Boardville	"	Cooper & Hewitt	Old forge site	10	....	....	Not in use.
Greenwood Lake Branch	West Milford	"	P. L. La Roe	Grist	11	18	30	
" " "	" " township	"	Albert Terhune	"	17	20	50	
" " "	" " "	"	Albert S. Terhune	Saw	14	10	16	
" " "	" " "	"	" "	"	20	16	26	
Pequannock River	Riverdale	Morris	East Jersey Water Co., Hon. J. F. Post, Lessee,	"	9	30	60	
" "	"	"	East Jersey Water Co., Hon. J. F. Post, Lessee,	Bark	8	12	24	
" "	"	"	East Jersey Water Co., Robert Slater, Lessee	Hatters' felt	14	60	87	
" "	Bloomingdale	"	East Jersey Water Co., W. G. Linnen, Lessee	Grist	12	12	30	

WATER-POWERS OF NORTHERN NEW JERSEY—Continued.

Passaic River and Branches—Continued.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED.		REMARKS.
						Net.	Gross.	
Pequannock River	Bloomingdale	Passaic	East Jersey Water Co., M. J. Ryerson's Heirs, Lessees	Grist	15	12	30	
" "	"	"	East Jersey Water Co., M. J. Ryerson's Heirs, Lessees	Turning	15	5	12	
" "	"	"	East Jersey Water Co., M. J. Ryerson's Heirs, Lessees	Saw	15	10	25	
" "	"	Morris	East Jersey Water Co., Bloomingdale Soft-Rubber Co., Lessees	Soft rubber	14	100	143	
" "	Butler	"	East Jersey Water Co	Paper-mill site	18			Not in use.
" "	"	"	Butler Hard-Rubber Co	Hard rubber	30	260	370	
" "	"	"	James C. Reynolds	Paper	15	100	143	
" "	"	"	Pequannock Valley Paper Co.	"	17	175	250	
" "	"	"	Demarest & Co	Excelsior	18	125	179	
" "	Smith's Mills	Passaic	East Jersey Water Co., H. D. Smith, Lessee	Grist	11	36	72	
" "	" "	"	East Jersey Water Co., Geo. and Thos. Smith, Lessees	"	10			Not in use.
" "	Charlottesburg	"	Cooper & Hewitt	Feed	14			" "
" "	"	"	" " "	Hardware	19			" "
" "	New Foundland	Morris	Bigelow Brothers	Saw	9	36	50	
" "	" "	Passaic	J. J. Laroe	Grist	6½	20	30	
" "	Stockholm	Morris		Old forge site	20			
" "	"	Passaic	A. M. Booth	Pocket-knife works	14	12	24	
" "	"	Sussex	Nancy Riggs	Old forge site	16			Not in use.
" "	Hardiston township	"	Naval H. Margin	" " "	12			" "
" "	" "	"	John E. Forgerson	Grist	22	24	40	
" "	" "	"	Amos Faber	Old saw				Not in use.
" "	" "	"	Isaac William Arden	" "	10			" "
Stockholm Branch	Stockholm	"	Mrs. Walter	Tannery	18	5	12	
" "	"	"	Edward Kincaid	Grist and distillery	20			Not in use.

WATER-POWERS OF NORTHERN NEW JERSEY—Continued.

Passaic River and Branches—Continued.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED.		REMARKS.
						Net.	Gross.	
Pacack Brook Branch	Stockholm	Sussex	John Lynn	Old forge site	15			Not in use.
" " "	Canistear	"	Ira Day and Adam Smith Estate	" " "	14			Not in use.
" " "	"	"	John Baxter	" " "	14			
" " "	"	"	Isaac Snyder	" saw-mill site	14			Not in use.
" " "	"	"	Ezra Day	" " " "	14			" "
Pine Brook	Westville	Essex	M. N. Crane	Feed and saw	23	20	33	
" "	"	"	Geo. B. Harrison	Grist	20			Not in use.
" "	Caldwell	"	Stephen R. Gould	Bark				" "
" "	"	"	George Budd	Old paper mill	25			Not in use.
" "	"	"	Dr. Charles H. Hunter	Snuff	10			" "
Rockaway River	Montville township	Morris	Heirs of Benj. Starkey	Woolen	7	20	50	
" "	" "	"	Albert Zabriskie	Grist	4½	24	34	
" "	Old Boonton	"	M. Fitzgibbons	Straw-board paper	30	260	370	
" "	Boonton	"	H. N. Hubbard	Foundry	23.58	15	25	
" "	"	"	" "	Agricultural machinery	49	25	40	
" "	"	"	Wrought-Iron Paint Co.	Paint	28.7	100	166	
" "	"	"	Boonton Iron and Steel Co.	Rolling mills	31.63	150	250	
" "	"	"	W. C. Boon & Co.	Drop forgings	31.87	30	50	
" "	"	"	O. Patterson	Nails	28.82	25	40	
" "	"	"	United States Aluminum Co.	Aluminum	29	160	267	
" "	"	"	Electric Light, H. and P. Co.	Electric lighting	31.87	43	72	
" "	"	"	Interchangeable Tool Co.	Tools		15	22	
" "	"	"	Lincoln Iron Works	Iron works		23	38	
" "	Powerville	"	Powerville Felt-Working Co. (Limited)	Roofing felt	10	188	270	
" "	Rockaway	"	Wm. F. Brann	Axe factory	8			
" "	"	"	E. D. Halsey	Grist	11	24	40	
" "	"	"	" "	Forge	11	15	40	
" "	"	"	" "	Saw	11	10	20	
" "	Dover	"	Dover Iron Co.	Rolling mills	9½	15	30	
" "	Port Oram	"	Luxembourg Improvement Co.	Hosiery	8	21	30	
" "	Baker's Mills	"	Henry and William Baker	Grist	10	24	48	
" "	" "	"	" " " "	Forge site	7			Not in use.

WATER-POWERS OF NORTHERN NEW JERSEY—Continued.

Passaic River and Branches—Continued.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED.		REMARKS.
						Net.	Gross.	
Rockaway River	Lower Longwood	Morris	A. A. Wilcox	Forge site	12	....	....	Not in use.
“ “	Upper Longwood	“	Hon. John Kean, Jr.	“ “	15	....	....	“ “
“ “	Woodstock	“	Zophar Tallmage	Distillery	7	....	....	“ “
“ “	Petersburg	“	David C. Wallace	Grist	12	15	20	
“ “	Milton	“	Enos Davenport's Estate	....	7	....	....	Not in use.
“ “	“	“	Horace Chamberlain	Grist	15	20	30	
“ “	“	“	“ “	Saw	12	10	20	
“ “	“	“	J. R. Riggs	Old Stanborough Forge	10	....	....	Not in use.
“ “	Russia	“	“ “	Old forge site	....	....	....	“ “
“ “	Hopewell	“	....	“ “ “	....	....	....	“ “
Montville Stream	Montville	“	Andrew Decker	Grist	21	15	30	
“ “	“	“	....	Print & dye works.	25	55	80	
“ “	“	“	J. Comley	Novelty works	18	50	70	
Dixon Pond Branch	Rockaway Valley	“	....	Grist-mill site	10	....	....	Not in use.
“ “ “	“ “	“	C. B. Dixon	Grist	23	15	25	
Den Brook Branch	Union	“	“ “	Old forge site	20	....	....	Not in use.
“ “ “	Shongum	“	....	Old paper-mill site.	12	....	....	“ “
“ “ “	“	“	Opennaki Association	Forge site	15	....	....	“ “
Beaver Brook	Beach Glen	“	A. W. Cutler	Saw-mill site	12	....	....	“ “
“ “	Meriden	“	....	Old forge site	10	....	....	“ “
“ “	Split Rock	“	....	“ “ “	8	....	....	“ “
Mill Brook	Mill Brook	“	Cobb Estate	Old furnace site	35	....	....	“ “
“ “	“ “	“	William E. Teed	Old distillery site	18	....	....	“ “
“ “	“ “	“	Adams Davenport	Grist	22	12	24	
“ “	“ “	“	“ “	Saw	16	10	20	
“ “	“ “	“	Thomas A. Lindsley	Old forge site	30	....	....	Not in use.
“ “	“ “	“	Martin and Isaac Searing	Old saw-mill site	10	....	....	“ “
“ “	“ “	“	James M. Bryant	Saw	14	10	20	
Green Pond Brook	Middle Forge	“	U. S. Government	Old forge site	15	....	....	Not in use.
“ “ “	Denmark	“	F. P. Merritt	“ “ “	30	....	....	“ “
Hard Bargain Brook	Hard Bargain	“	Stephen Strait's Estate	“ “ “	....	....	....	“ “
Whippany River	Whippany	“	George Ball	Grist	7	18	30	
“ “	“	“	Henry Conger	Cotton	15	70	120	Idle.
“ “	“	“	McEwan Brothers	Paper	19	60	100	
“ “	“	“	Diamond Mills Paper Co.	“	28	100	145	

WATER-POWERS OF NORTHERN NEW JERSEY—Continued.

Passaic River and Branches—Continued.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED.		REMARKS.
						Net.	Gross.	
Whippany River	Monroe	Morris	James A. Muir	Paper	17	66	100	
" "	"	"	J. F. Muir	"	18	....	....	
" "	Morristown	"	Martin & Caskey	Grist	5	18	30	
" "	"	"	Mary Slagle	"	8	18	30	
" "	"	"	Heirs Stephen Vail	Turning	7	30	60	
" "	"	"	" " "	Machine shop	7	60	120	Not in use.
" "	Brookside	"	Aaron Whitehead	Grist	28	38	60	
" "	"	"	M. M. & E. J. Connet	Flouring	30	38	60	
" "	"	"	E. J. Connet	Saw	24	22	35	
Branch at Troy Hills	Troy Hills	"	George B. Smith	Grist	19	15	30	
" " " "	" "	"	" " "	Turning	19	6	10	
" " " "	" "	"	" " "	Saw	21	11	19	
" " Malapardus	Whippany	"	B. F. Howell	"	15	12	30	
" " "	"	"	" "	Machine shop	15	6	12	
" " Speedwell	Morristown	"	Mrs. John Ledgewood	Grist	20	12	30	Not in use.
" " "	"	"	" " "	Foundry site	12	....	....	" "
North Branch of Whippany	Morris Plains	"	J. H. Branat	Paper	20	50	100	
" " " "	" "	"	F. W. Jaqui	Flouring	27	70	100	
" " " "	" "	"	J. Fletcher Johnson	Cider	25	....	....	Not in use.
" " " "	" "	"	Arthur Thompson	Saw	8	....	....	Old site not in use.
" " " "	Tabor	"	A. W. Cutler	Feed and saw	15	5	10	
Canoe Brook	Millburn township	Essex	Geo. W. Reeves	Saw-mill site	15	....	....	Not in use.
" "	Livingston township	"	F. C. Reilly	Grist-mill site	7	....	....	" "
Dead River	Liberty Corner	Somerset	Abram Ten Eyck	Saw-mill site	....	....	....	" "
Branch near Logansville	Logansville	Morris	Van Doren Phœnix	Grist	15	12	30	
Branch at Pleasantville	Pleasantville	"	Joseph Hoar	Saw	10	10	20	
" " Green Village	Green Village	"	Joseph Dixon	"	10	....	....	Not in use.
" " " "	Silver Lake	"	H. M. Olmstead	Flouring	12	52	75	

WATER-POWERS OF NORTHERN NEW JERSEY—Continued.

Hackensack River and Branches.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED.		REMARKS.
						Net.	Gross.	
Hackensack River	Oradell	Bergen	William Veldran	Saw	4	10	14	
" "	"	"	" "	Grist	4	70	100	
" "	Harrington	"	John J. Bogert	"	4½	25	35	
" "	Rivervale	"	C. O. Colligan	Chair factory	6½	20	30	
" "	"	"	" "	Saw	6½	10	20	
" "	"	"	" "	Wheelwrights' supplies	6½	20	30	
" "	"	"	Hiram Bellis	Grist and saw	6	....	....	Not in use.
Branch at Overton	Overton	"	John C. Meister	" " "	12	12	30	
" " "	Schraalenburg.	"	Cranmond Kenedy	Grist	10	....	....	Not in use.
" " "	"	"	Sarah Demarest	"	9	12	24	
" " "	Bergen Fields	"	W. S. Bogert and Henry Cooper	Chair factory	8	8	10	
" " "	" "	"	W. S. Bogert and Henry Cooper	Saw	8	10	20	
" of Trenekill	Harrington	"	Maria Demarest	Grist	6	....	....	Not in use.
" " "	Cresskill	"	J. D. Farrington	Saw and grist	12	....	....	" "
" " "	"	"	J. R. & V. B. Demarest	Hardware and brass	16	45	60	
" " "	"	"	Hon. W. W. Phelps	Saw	18	....	....	Not in use.
" " "	Closter	"	Moses T. Taylor	"	12	8	20	
" " "	"	"	D. Bingham	Grist	....	....	....	Not in use.
Pascack Creek	Westwood	"	Jacob R Hopper	Saw	7	8	20	
" "	"	"	Robert Yates	Grist and saw	7	36	72	
" "	Pascack	"	W. B. Ackerman	Saw	7½	10	15	
" "	Park Ridge	"	George Van Riper	Bobbins	....	....	....	Not in use.
" "	" "	"	Catharine Pretre	Grist	7	12	20	
" "	Montville	"	Garret J. Herring	Bent wagon wood	12	15	30	
" "	"	"	Philip Beckeile	Saw	12	8	15	
Musquapsink Creek	Westwood	"	Isaac D. Bogert	Grist	6	12	24	
" "	"	"	" "	Saw	6	10	20	
" "	Hillsdale	"	Henry C. Storms	"	12	8	16	
" "	Pascack	"	Paul Bates	Grist	18	....	....	Not in use.
Bear Brook	Park Ridge	"	John Cummings	"	18	12	24	
" "	" "	"	James Leach	Chair factory	18	....	....	Not in use.
Upper Montvale Branch	" "	"	J. H. Wield & Co	Bobbin "	18	23	32	

WATER-POWERS OF NORTHERN NEW JERSEY—Continued.

Elizabeth River and Branches.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED.		REMARKS.
						Net.	Gross.	
Elizabeth River	Salem	Union	John Kean	Grist	10	12	22	
" "	Irvington	Essex	William A. Ostrander	"	22	24	35	
" "	"	"	Elias Durran	......	......	......	......	Not in use.
" "	"	"	Mahlon S. Drake	Rule factory	20	......	......	" "
West Branch of Elizabeth River	Salem	Union	John Kean	Saw	18	......	......	" "

Rahway River and Branches.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. Net.	H. P. Gross.	REMARKS.
Rahway River	Rahway	Union	John Fedder Estate	Grist-mill site	10	......	......	Not in use.
" "	Cranford	"	Taylor, Bloodgood & Co.	Woolen	6⅚	28	40	
" "	"	"	John A. Morrough	Grist	8	30	45	
" "	"	"	Elias Vreeland Estate	Saw	5½	18	30	
" "	Milltown	"	J. Edgar Meeker	Paper	7 }	30	50	
" "	"	"	" "	Saw	7 }	10	20	
" "	Millburn	Essex	A. L. Henderson	Paper	15	20	30	
" "	"	"	Charles A. Lighthipe	Hat factory site	16	......	......	Not in use.
" "	"	"	" " "	Hat bodies	22	100	170	Not working.
" "	"	"	Diamond Mills Paper Co.	Paper	27	25	40	
Robinson's Branch	Rahway	Union	M. H. Acken	Flouring	13½	15	25	
" "	Clark township	"	Martin Fate	Mill site	6 ?	......	......	Not in use.
" "	Willow Grove	"	John Lambert	Grist	22	12	20	
Normahiggin Brook	Branch Mills	"	Silas Miller	"	11	12	22	
" "	" "	"	C. T. & A. M. Parkhurst	Paper and feed	16	25	50	
East Branch of Rahway	Maplewood	Essex	H. O. Pierson	Flouring	13	25	35	
" " "	Millburn	"	William Smith	Grist	10	......	......	Not in use.
" " "	"	"	......	Wall paper	15	......	......	Not used.
" " "	Springfield	Union	Frederick Crane Chemical Co.	Paper mill site	15	......	......	Not in use.
" " "	"	"	Frederick Crane Chemical Co.	Chemical works	16	......	......	Power not used.
" " "	"	"	—— Jennings	Paper-mill site	12 ?	......	......	Not in use.
" " "	Summit	"	William H. Bryant	Saw	10	6	12	

WATER-POWERS OF NORTHERN NEW JERSEY—Continued.

Raritan River and Branches.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED.		REMARKS.
						Net.	Gross.	
Raritan River	New Brunswick	Middlesex	Norfolk and New Brunswick Hosiery Co.	Hosiery	11	150	215	
" "	Raritan	Somerset	Wm. W. Adair & Co.	Flouring	12½	62	90	
" "	"	"	Rynear Veghte	Paint	14	36	50	
" "	"	"	Raritan and Somerville Water Co.	Pumping station	16	85	110	
" "	"	"	Wm. H. H Wyckoff	Grist	14	20	35	
South River	Bloomfield Mills	Middlesex	Bloomfield Mills Co.	Licorice and spice	7¼	112	160	
" "	Spottswood	"	A. A. Devoe	Grist	8	24	48	
" "	"	"	" "	Snuff	8	30	60	
" "	Helmetta	"	Geo. W. Helme & Co.	"	8	12	20	
" "	Jamesburg	"	James Buckelew Estate	Flouring	14	80	100	
" "	"	"		Shirt factory	13	125	180	
Tennent's Brook	Old Bridge	"	Perth Amboy City	Mill site	11			Not in use.
Deep Run	Dill's Mills	"	Leonard A. Bampton	" "				" "
" "		"	—— Peters	Saw-mill site				" "
" "		Monmouth	Cor. Hanus	Grist " "				" "
Iresick Brook		"		Mill site				" "
Matchaponix Brook	Spottswood	"	Wm. A. Skinner	Snuff				
" "	Texas	"	Mrs. Amanda Garner	Mill site				Not in use.
" "	Matchaponix	"	Bloomfield Mills Co.	" "	6½			" "
" "	Mount's Mills	"	Perrine Estate	Flouring and saw	8	40	70	
" "	Englishtown	"	Wm. H. Parker	" " "	11	40	70	
McGelliard's Brook	"	"	J. W. Taylor	" " "	10	35	60	
" "	Near Freehold	"	Haight Estate	Flouring	22	45		Not in use.
Milford Brook	Lafayette Mills	"	L. Journee	Grist				" "
Wemrock Brook	West Freehold	"	Jas. A. Perrine	Grist and cider	22	20	30	
Manalapan Brook	Black's Mills	"	C. H. Snyder & Son	Flouring	16	63		
" "	" "	"	" " "	Saw	16			
" "	Oakland Mills	"	Jas. S. Parker	Grist	11	36	50	
" "	Smithburg	"	Robt. S. Blaine	Woolen	12	9	13	
" "	"	"	Wm. Hendrickson	Saw	12	13	20	
" "	Charleston Springs	"	J. Segoine	"	11	36	50	
Lawrence's Brook	New Brunswick	Middlesex	City of New Brunswick	Water works	15	216	300	
" "	Milltown	"	Meyer Rubber Co.	Rubber works	7⅔	70	100	
" "	Brookford	"	James Parsons	Snuff		15	25	

WATER-POWERS OF NORTHERN NEW JERSEY—Continued.

Raritan River and Branches—Continued.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED.		REMARKS.
						Net.	Gross.	
Lawrence's Brook	Davidson's Mills	Middlesex	C. C. Beekman	Grist	11	17	24	
“ “	Deans	“	Aaron Dean	Grist and saw	9½	45	75	
Branch of Lawrence's Brook	Baptist Lane	“	Dr. Smith	Cider	14	4	8	
Grog Brook		“	William P. Hageman	Grist	17	16	32	
Branch at Bloomington	Bloomington	Somerset	William Voorhees	“	12	15	25	
Bound Brook	Near Bound Brook	“	J. H. Sebring	Grist and saw	4½	15	30	
“ “	New Market	Middlesex	M. Otto	Grist	8	25	50	
“ “	New Brooklyn	“	H. J. Baker & Bro.	“	9	28	40	
“ “	“ “	“	Lehigh Valley R. R. Co.	Water tank and saw-mill	4½	10	14	
Green Brook	Green Brook Road	Somerset	William Holman	Grist	5½			Not in use.
“ “	Plainfield	“	Andrew Cadmus Estate	Saw	5			“ “
“ “	“	Union	French Bros.	Flouring	17	37	52	
“ “	“	Somerset	Charles Hyde	Grist	12	35	58	
“ “	Scotch Plains	“	Harper, Hollingsworth & Darby	Fur factory	22	54	77	
“ “	“ “	“	E. A. Seeley	Paper	3	25	50	
Middle Brook	Bound Brook	“	Bound Brook Water Co.	Grist	38½	31	44	
Millstone River	Weston	“	Henry Conger	Hat factory	4¾	18	36	
“ “	Blackwell's Mills	“	E. B. Cook	Flouring	4	50	82	
“ “	Griggstown	“	Charles Dixon	Grist	4	30	50	
“ “	Rocky Hill	“	Isaac Shaw	“	4	40	80	
“ “	Kingston	Middlesex	Charles B. Robinson	“	3½			Not in use.
“ “	Aqueduct	“	The Misses Gray	Flouring	5	25	50	
“ “	Westcott's Mills	“		Grist	10			Not in use.
“ “	Bergen's Mills	Monmouth	—— Davison	“	11	27	39	
Beden's Brook	Stoutsburg	Somerset	J. Hervey Stout	Grist and saw	10	26	42	
No Pike Brook	Bridge Point	“	Wm. S. Terhune	Grist	6	21	35	
Stony Brook	Princeton	Mercer	Joseph H. Brewer	“	8	23	40	
“ “	Rosedale	“	A. B. Reeder	“	10	17	30	
“ “	“	“	“ “	Saw	10	12	20	
“ “	Pennington	“	Charles A. Reed	Grist	9	13	26	
“ “	Titus' Mills	“	W. W. Titus	Flouring	7	25	36	
“ “	Moores	“	Joseph H. Moore	“	8½	25	36	
“ “	“	“	“ “	Saw	8½	10	20	
“ “	Lindvale	“	Robert Crosedale	Grist				

WATER-POWERS OF NORTHERN NEW JERSEY—Continued.

Raritan River and Branches—Continued.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED.		REMARKS.
						Net.	Gross.	
Beden's Brook	Rock Mill	Mercer	Geo. Anderson	Saw	......	......	......	Not in use.
" "	" "	"	Peter Gray	"	......	......	......	
Bear Brook	Princeton Junction	"	J. H. Grover	Flouring	11	30	50	
Cranbury Brook	Plainsboro	Middlesex	—— Lovett	Grist	8	20	33	
" "	Cranbury	"	John Petty	"	7	12	20	
Rocky Brook	Hightstown	Mercer	G. W. Norton	Flouring	10	28	40	
" "	Etna	"	Charles Keeler	Grist and saw	12	40	57	
" "	Perrineville	Monmouth	Charles Allen	Grist	22	40	50	
Hutchinson's Brook	Ely's Mills	Mercer	S. D. Ely	"	9	40	57	
North Branch	Milltown	Somerset	Heirs of Michael Van Derveer	Flouring	6	36	50	
" "	North Branch	"	Tunison & Beekman	"	4	36	50	
" "	Bedminster	"	Jacob Kline	Grist and saw	6	10	20	
" "	Pluckamin	"	Thomas Moore	Grist-mill site	7½	......	......	Not in use.
" "	Hub Hollow	"	Ludlow & Bedell	Feed and saw-mill and hub factory	10	35	60	
" "	Mendham township	Morris	Peter Z. Smith	Saw	12	20	30	
" "	Chester township	"	J. Wesley Swackhamer	Grist	9½	29	40	
" "	Roxiticus	"	Aaron Hoffman	Old mill site	6	......	......	Not in use.
" "	"	"	Sarah Lidell	Grist	23	25	50	
Lamington River	Burnt Mills	Somerset	N. Welch	"	5	25	50	
" "	Vliet's Mills	"	George Moore	"	9	12	25	
" "	" "	"	" "	Saw	9	10	20	
" "	" "	"	William Rhinehart	Creamery	4	3	6	
" "	Pottersville	Hunterdon	Robert Craig	Flouring	7½	40	60	
" "	"	"	" "	Grist	17	26	35	
" "	"	"	H. M. Sovereign & Son	Foundry and machineshop.	16	107	150	
Rockaway Creek	White House	"	William H. Reger	Flouring	9	21	30	
South Branch of Rockaway	Lebanon	"	Isaac P. Hoffman	"	23	25	35	
North Branch of Rockaway	White House	"	Mrs. C. S. Hall	Grist	24	40	80	
" " "	New Germantown	"	John Lane	"	......	......	......	
" " "	" "	"	" "	Woolen	......	......	......	
" " "	Tewksbury township	"	David Reed	Saw	12	10	20	
" " "	Mountainville	"	Robert Craig	Grist	9	12	24	
" " "	"	"	Jonathan Potter	Distillery	8	2	4	

WATER-POWERS OF NORTHERN NEW JERSEY—Continued.

Raritan River and Branches—Continued.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED.		REMARKS.
						Net.	Gross.	
North Branch of Rockaway	Mountainville	Hunterdon	J. N. Wilcox	Grist	22	12	24	
“ “ “	Fairmount	“	Frederick Hoffman	Saw	20	10	20	
“ “ “	“	“	Geo. B. Sutton	Tannery	15	10	20	
“ “ “	“	“	“ “	Saw	15	10	20	
“ “ “	“	“	Andrew Philhower	Grist	20	25	50	
Cold Brook	New Germantown	“	Peter W. Melick	Flouring	20	24	34	
Pottersville Brook	Pottersville	Somerset	John C. Latourette	Grist	12	7	14	
Black River	“	Morris	Robert Craig	Saw	12	40	60	
“ “	Hacklebarney	“	John H. Miller	Flouring	18	58	82	
“ “	“	“	“ “	Saw	13	10	15	
“ “	“	“	Chester Iron Co					
“ “	“	“	“ “ “					
“ “	Milltown	“	William Cardovin	Carding	9	16	32	
“ “	“	“	A. W. Cooper	Grist	17	60	100	
Milltown Branch	“	“	Richard Stevens	Distillery	20	8	16	
Tanner's Brook	Washington township	“	John Castner	Saw	7	10	20	
“ “	“ “	“	“ “	Cider	7	5	10	
“ “	Parker	“	Jacob Lauerman	“	11	8	16	
Mine Brook	Mine Brook	Somerset	James Dow	Feed and saw	18	10	20	
“ “	Barker's Mills	“	C. Barker	Flouring	35	27	40	
“ “	Bernardsville	“	T. G. & J. V. Bunn	Grist and distillery	26	35	50	
“ “	“	“	Charles McMichael	Flouring	28	14	20	
Peapack Brook	Schomp's Mill	“	William A. Schomp	Grist	10	14	23	
“ “	Peapack	“		“				
“ “	Gladstone	“	Lewis Van Doren	Old mill site				Power not used.
Branch below Roxiticus	Mendham township	Morris	S J. Shurts	Saw	22	10	20	
Burnett Brook	Roxiticus	“	J. R. Nesbitt	Grist	24	25	40	
“ “	Mendham township	“	Peter Cramer	Saw	12			Not in use.
“ “	“ “	“	James Able	Grist and saw	13	20	40	
Indian Brook	“ “	“	James H. Lawry	Grist	24	50	82	
South Branch	South Branch	Somerset	Theodore Amerman	Flouring	6½	45	64	
“ “	“ “	“	“ “	Saw	6½	10	20	
“ “	Neshanic Station	“	Andrew Lane	Flouring	6′ 10″	80	114	
“ “	Riverside	“	G. C. Higgins & Bro	“	5½	75	107	
“ “	Three Bridges	Hunterdon	John C. Hopewell's Estate	“	5	50	70	
“ “	Flemington	“	Kershow & Chamberlain	Grist	5	40	60	

WATER-POWERS OF NORTHERN NEW JERSEY—Continued.

Raritan River and Branches—Continued.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED.		REMARKS.
						Net.	Gross.	
South Branch	Stover's Mills	Hunterdon	Isaac Stover	Flouring	6	55	80	
" "	" "	"	" "	Saw	6	15	20	
" "	" "	"	" "	Flax	6	....	....	Not in use.
" "	Rowland Mills	"	Ellen Cokesfair	Grist	6	40	60	
" "	Sunnyside	"	L. Cramer	"	9	40	60	
" "	Hamden	"	C. V. Dilley	Flouring	8	40	60	
" "	"	"	M. C. Cramer	Grist	5	20	40	
" "	Clinton	"	E. V. Parry	Flouring	7½	40	60	
" "	"	"	Philip Gulick	Grist	7	40	60	
" "	High Bridge	"	Charles Conover	"	8½	23	40	
" "	" "	"	E. Doreland & Sons	Flouring	7½	80	110	
" "	" "	"	Taylor Iron Works	Foundry	14	210	300	
" "	" "	"	" " "	Forge	33	520	750	
" "	Readingsburgh	"	John Hockenbury	Saw	8	....	....	Not in use.
" "	"	"	G. W. Alpaugh	Flouring	14	100	140	
" "	"	"	" "	Saw	8	15	20	
" "	High Bridge township	"	Abram Hoffman	"	5	10	20	
" "	Califon	"	B. Cole	Grist	7½	25	40	
" "	"	"	" "	"	6½	25	40	
" "	"	"	" "	Feed	8	12	20	
" "	Tewksbury township	"	L. H. Trimmer	Grist	4½	25	50	
" "	Middle Valley	Morris	H. P. Dufford	"	6	35	60	
" "	German Valley	"	Henry Fleming	"	7	25	40	
" "	" "	"	Henry Weise	Saw	7½	15	30	
" "	Naughright	"	Andrew Dufford	Grist	3½	25	40	
" "	"	"	Jacob Naughright	"	5	15	25	
" "	Bartley	"	Wm. Bartley & Sons	Foundry and machine.	10	25	34	
" "	"	"	" " "	Saw	10	21	30	
" "	"	"	J. M. Conover	Flouring	14	38	54	
" "	"	"	Heirs of Joshua Solomon	Old Forge	....	....	....	Not in use.
" "	Mount Olive	"	Richard Stephens & Co.	Flouring	22	40	57	
" "	" "	"	" " "	Saw	33	45	75	
Holland's Brook	Readington	Hunterdon	Peter S. Nevius	Grist and saw	8	12	30	
Neshanic River	Hillsborough township	Somerset	J. E. Adams	Feed and wood	10	28	40	
" "	Clover Hill	Hunterdon	George Rae	Grist	9	36	90	

WATER-POWERS OF NORTHERN NEW JERSEY—Continued.

Raritan River and Branches—Continued.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED.		REMARKS.
						Net.	Gross.	
Neshanic River	Copper Hill	Hunterdon	William Hill	Feed and bone	6	36	60	
“ “	Sand Brook	“	H. Moore	Grist	30	24	40	
“ “	Grover	“	John C. Carrell	“	26	36	50	
Prescott's Brook	Allertown	“	Geo. Stryker	Grist and saw	14	16	40	
“ “	Round Valley	“	Isaac P. Hoffman	Grist	18	24	40	
Hamden Branch	Hamden	“	Fanny Grant	Grist and saw	22	12	24	
Cakepoulin Creek	Sidney	“	Henry Dusenbury	Grist	15	35	50	
“ “	“	“	Samuel Stevenson	Paint				Not in use.
“ “	Kingstown	“	Archer Taylor	Grist	12½	24	48	
“ “	Pittstown	“	William M. Taylor	“	16	12	20	
“ “	“	“	Hiram Deats.	Foundry and machine shop.	28	20	30	
“ “	“	“	E. H. Deats	Saw	21	15	20	
“ “	Littletown	“	Daniel Little	Grist	30	15	20	
Midvale Branch	Midvale	“	James Voss		15	10	20	
Beaver Brook	Annandale	“	Joseph Hampton	Grist	24	22	30	
Mulhockaway Creek	Union township	“	I. H. Butler	“	12	12	24	
“ “	Pattenburgh	“	W. T. Bird & Bro	“	28	24	48	
Spruce Run	Union township	“	Joseph H. Exton	Saw	20	17	24	
“ “	“ “	“	“ “	Flouring	24	40	57	
“ “	Glen Gardner	“	T. Edgar Hunt	Peach baskets	22	35	50	
“ “	“ “	“	“ “ “		14			Not in use.
“ “	“ “	“	G. F. Painter	Grist	20	19	38	
“ “	Clarksville	“	T. Frank Cawley	“	18	21	35	
“ “	Newport	“	Benjamin Apgar	“	28	20	40	
“ “	“	“	Isaiah Bryant	Saw	12	10	17	
“ “	“	“	Josiah Apgar	Grist	21	24	40	
Branch at Schooley's Mt	Schooley's Mountain	Morris	J. V. Stryker	Saw	15	8	20	
Drake's Brook	Flanders	“	D. G. Vliet	Grist	8	18	36	
“ “	“	“	S. H. Dorland	Flouring	14	50	70	
“ “	Drakesville	“	R. H. Cary	“	15	42	60	
Branch at Flanders	Flanders	“	H. M. Sovereign	Woolen	23	12	17	
“ “ “	“	“	P. A. Hoffman	Grist	31	33	55	

WATER-POWERS OF SOUTHERN NEW JERSEY.

Assanpink Creek and Branches.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED.		REMARKS.
						Net.	Gross.	
Assanpink Creek	Trenton	Mercer	Star Rubber Co.	Rubber	12½	100	143	
" "	"	"	Whitehead Bros.	"	7	80	115	
" "	Lawrence Station	"	G. W. Davenport	Flouring and grist	5	45	50	
" "	Windsor	"	Amos Hutchinson	Grist	10	45	70	
Miry Run	East Trenton	"	E. C. Hutchinson	Flouring	4	11	15	
" "	Mercerville	"	J. Reid	"	5	11	20	
" "		"	H. H. Hutchinson	Grist	12	25	35	

Crosswicks Creek and Branches.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED.		REMARKS.
						Net.	Gross.	
Crosswicks Creek	Groveville	Burlington	Wm. McK. Morris, Edw. J. Morris	Cotton factory	7	40	57	
" "	Crosswicks	"	—— Buzbee	" "	9 }	25	35	
" "	"	"	" "	Saw	9 }	15	22	
" "	Walnford	Monmouth	Miss S. Hendrickson	Grist	3	32	46	
" "	New Egypt	Ocean	Walter Lamb	Flouring	6	50	70	
" "	Hockamick	Burlington	Levi Parker	Saw	10	40	60	
" "	Brindletown	"	M. Hutchinson	"	12	30	45	
North Run	Cookstown	"	L. D. Woodward	Flouring	13	24	35	
" Branch	Near Wrightstown	"	Mrs. Annie Davis	Grist	12	25	38	
Back Creek	Yardville	Mercer	D. S. Hutchinson	Flouring	22	36	55	
Doctor's Creek	"	"	C. Hutchinson	"	10 }	35	50	
" "	"	"	" "	Saw	10 }	30	50	
" "	Allentown	Monmouth	J. Darnell & Bro.	Flouring	9	35	50	
" "	"	"	A. Cafferty	"	10	25	36	
" "	Imlaystown	"	Reuben Hendrickson	"	10	25	36	
" "	Red Valley	"	J. Dawes	Grist	10	20	30	
Branch at Crosswicks	Crosswicks	Burlington	—— Buzbee	Plaster	9	30	45	
Cream Ridge Branch	Cream Ridge	Monmouth	—— Kirby	Grist	10	20	30	
Lahaway Creek	Hornerstown	"	E. Emson	"	8 }	25	36	
" "	"	"	" "	Saw	8 }	10	15	
" "	Prospertown	"	" "	Flouring	9	35	50	

WATER-POWERS OF SOUTHERN NEW JERSEY—Continued.

Crosswicks Creek and Branches—Continued.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL	H P. UTILIZED.		REMARKS.
						Net.	Gross.	
Lahaway Creek	Prospertown	Monmouth	E. Emson	Saw	9	15	20	
" "	Lahaway Plantation	Ocean	A. Van Hise	"	5	10	15	
Branch at New Egypt	New Egypt	"	Chas. Cannon	Flouring	20	17	24	

Black's Creek and Branches.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL	Net.	Gross.	REMARKS.
Black's Creek	Bordentown	Burlington	M. L. Dunn	Flouring and grist	12	35	50	
" "	Recklesstown	"	C. C. Stillwell	Grist	13	30	45	
" "	"	"	Chas. E. Wallace	Flouring and grist	8½	30	45	
Kinkora Creek	Three Tuns	"	David Ashby	Grist	9	17	25	
" "	Columbus	"	—— Kirlin	Saw	5	8	12	

Assicunk Creek and Branches.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL	Net.	Gross.	REMARKS.
Branch at Deacon's	Burlington	Burlington	Edw. & Geo. Riggs	Grist	9	17	25	

Rancocas Creek and Branches.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL	Net.	Gross.	REMARKS.
Mill Creek	Charleston	Burlington	M. Pricket	Grist	8	25	35	
North Branch Rancocas	Mount Holly	"	Richard C. Shreve	Flouring	8	71	100	
" " "	" "	"	" "	Saw, sash and blind	7	30	45	
" " "	Smithville	"	Smith Estate	Machinery	7	135	200	
" " "	Birmingham	"		Mill site				Pleasure gr'ds.
" " "	Pemberton	"	Anthony J. Morris	Flouring	7¼	60	80	
" " "	"	"	" "	Saw	7¼	10	20	
" " "	New Lisbon	"	Eayre Oliphant	Grist	9	21	40	
" " "	" "	"	" "	Saw	9	10	20	

WATER-POWERS OF SOUTHERN NEW JERSEY—Continued.

Rancocas Creek and Branches—Continued.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED.		REMARKS.
						Net.	Gross.	
North Branch Rancocas	Brown's Mills	Burlington			9			Pleasure gr'ds.
" " "	Hanover Furnace	"	Lawrence Pepper		10			Not in use.
Birmingham Branch	Pemberton	"	Wm. Williams	Grist	3	20	30	
Mount Misery Brook	Mary Ann Furnace	"	Geo. B. Upton	Mill site	8			Cranberry bog.
" " "	Mount Misery	"	" "	" "	8			Not in use.
Lower Mill Branch	Lower Mill	"	Alfred L. Black	Saw	7	15	30	
" " "	Upper Mill	"		Mill site				Not in use.
South Branch Rancocas	Eayrstown	"	Sarah B. Githens	Flouring	8	70	100	
" " "	"	"	" "	Saw	8	15	20	
" " "	Vincentown	"	John S. Irick	Flouring	8	70	100	
" " "	"	"	" "	Saw	8	15	20	
Mason's Creek	Union Mills	"	H Darnell	Grist-mill site				Not in use.
Haynes' Creek	Wilkins' Station	"	Kirby Bros.	Flouring	7	50	75	
" "	" "	"	" "	Saw	7	12	18	
" "	Medford	"	Jos. C. Hinchman	Grist	11	23	33	
" "	"	"	" "	Saw	11	15	25	
" "	Ballinger's Mills	"	" "	Grist	24	18	30	
Kettle Run	Taunton	"	" "	Cranberry cleaning	9	12	20	
" "	Braddock's Mills	"	Edw. Braddock	Saw	17	15	25	
Barton's Run	Jennings' Mill	"	Wm. Tomlinson	Flouring and grist	11	23	33	
" "	Milford	"	M. Powell	Grist	10	12	20	
" "	Near Milford	"	Jos. Evans	Saw	9	18	30	
Burr's Mill Branch	Burr's Mills	"	John S. Irick	"		10	15	
Friendship Creek	Friendship	"	Albert Jones	Saw-mill site				Not in use.

Swedes Run.

Swedes Run	Fairview	Burlington	Haines Bros.	Flouring and grist	12	25	37	
" "	Chesterville	"	Wm. Buckman	Grist	9	17	25	

WATER-POWERS OF SOUTHERN NEW JERSEY—Continued.

Pompeston Creek.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED.		REMARKS.
						Net.	Gross.	
Pompeston Creek	Parry	Burlington	H. Lippincott	Saw	9	15	22	
Cooper's Creek.								
North Branch	Marlton	Camden	Hopkins Estate	Grist	12	(8)	....	Not in use.
Cooper's Creek	Haddonfield.	“	Jos. G. Evans	“	11	30	43	
“ “	Kirkwood	“	Knickerbocker Ice Co.	“	18	50	70	
“ “	Gibbsborough	“	—— Lucas	“	8	30	45	
“ “	“	“	—— Blakely	Saw	8	20	33	
Branch at Haddonfield	Haddonfield	“	Hopkins Estate	Grist	22	....	....	Not in use.
Tindale's Run	“	“	Wilson Ice Co.	....	15	....	....	“ “
Branch	Near Ashland	“	Joseph Kay	Grist-mill site	24	....	....	“ “
Newton Creek.								
Main Branch	Cuthbert's	Camden	J. J. Schuetzius	Flouring	14	30	45	
“ “	Westmont	“	James Flynn	Paint and varnish	15	22	31	
Timber Creek and Branches.								
North Branch	Laurel Mills	Camden	E. Tomlinson	Grist	12	50	70	
“ “	Clementon	“	Theodore Gibbs	“	10	36	60	
Almonesson Creek	Almonesson	Gloucester	John Kennedy	“	18	35	50	
South Branch	Good Intent	Camden	J. Livermoor and others	“	11	22	30	
“ “	Grenloch	“	E. S. & F. Bateman	Agricultural implements	14	100	145	
“ “	Prosser's Mills	Gloucester	Thos. Boody	Grist	10	25	45	

WATER-POWERS OF SOUTHERN NEW JERSEY—Continued.

Timber Creek and Branches—Continued.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED.		REMARKS.
						Net.	Gross.	
South Branch	Turnersville	Gloucester	—— Turner	Saw	10	14	20	
Little Lebanon	"	"	A. W. Nash	Grist	10	36	50	
" "	Near Turnersville	"	J. Prosser	Saw	10	32	45	

Mantua Creek and Branches.

Mantua Creek	Near Hurffville	Gloucester	S. O. Bricket	Grist	13	25	42	
" "	Dilkesborough	"	Thos. Reeves	"	15	25	42	
Edwards' Run	Near Mantua	"	Chas. Jessop	"	12	30	42	
" "	" "	"	Samuel Boody	"	12	15	25	
Chestnut Branch	" Barnsboro	"	P. Avis	"	15½	20	28	
" "	Pitman Grove	"	G. W. Carr	Saw, sash and blind	6	30	45	
Wenonah Branch	Near Wenonah	"	The Wenonah Water Co.	Creamery	17	4	6	
Monongahela Brook	" "	"		Mill site	10	(15)		Not in use.
Dilkesborough Branch	Dilkesborough	"	W. Jessop	Saw mill	10	15	20	

Repaupo Creek.

Purgey Brook	Tomlin's Station	Gloucester	Simeon Warrington	Grist	13	24	35	

Little Timber Creek.

Little Timber Creek	Near Asbury Station	Gloucester	H. B. Hendrickson	Saw and distillery	10	20	30	

WATER-POWERS OF SOUTHERN NEW JERSEY—Continued.

Raccoon Creek and Branches.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED.		REMARKS.
						Net.	Gross.	
Raccoon Creek	Mullica Hill	Gloucester	J. Mount	Grist	12	30	45	
" "	Ewan's Mill	"	D. B. Brown	"	10	20	35	
Swedesboro Branch	Swedesboro	"	B. H. Black	Flouring	18	50	70	
" "	Near Swedesboro	"	David Russell	Grist	15	25	42	

Oldmans Creek and Branches.

Oldmans Creek	Harrisonville	Salem	(?)	Grist	16	50	75	
" "	Avis Mills	"	Paul H. Avis & Son	"	12	30	45	
" "	" "	"	" " "	Saw	12	10	15	
Oldmans Creek Branch	Near Harrisonville Station	Gloucester	Geo. Robinson	Grist	16	18	24	
" " "	" " "	"	—— Vanderbilt	"	20	12	20	

Salem Creek and Branches.

Salem Creek	Sharptown	Salem	A. Oliphant	Grist	7	20	33	
" "	Woodstown	"	I. L. Davenport	Flouring	10	34	50	
" "	East Lake	"	J. Webster	"	12	40	57	
" "	Richmanville	"	J. McCoster	"	16	30	50	
" "	Paulding	"	Wood Bros.	Saw and plaster	10	30	43	
" "	Daretown	"	Fox Bros.	Grist	14	16	23	
Two Penny Run	Upper Penn's Neck	"		Mill site	7			Not in use.

Alloways Creek and Branches.

Alloways Creek	Alloway	Salem	Diament & Bro	Flouring	14	56	80	
Deep Run Branch	Near Alloway	"	Wm. Elkin	Grist	12	30	50	
" " "	" "	"	Jacob House	Saw	10	15	22	
" " "	Friesburg	"	C. Dilkes	"	10	15	22	

WATER-POWERS OF SOUTHERN NEW JERSEY—Continued.

Alloways Creek and Branches—Continued.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED.		REMARKS.
						Net.	Gross.	
Cedar Brook	Near Alloway	Salem	J. Hitchnor	Grist	10	25	36	
Cool Run	" Aldine	"	J. Watson	Saw	12	12	17	
" "	Aldine	"	S. R. Ballinger	Grist	14	35	60	
Daretown Branch	Yorketown	"	David Harris	"	13	20	30	

Stow Creek and Branches.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	Net.	Gross.	REMARKS.
Upper Branch	Maskell's Mill	Salem	Maskell Estate,	Grist	9	30	42	
" "	Near Berry's Chapel	"	Mrs. Ad. Sinnickson	Flouring	18	40	60	
Bishop's Run	" Jericho	"	D. Harris	Grist	13	22	30	
Horse Run	Jericho	"	Mrs. Dr. Clark	"	11	25	36	
" " Branch	Near Jericho	"		Saw	12	20	30	
Newport Creek	Roadstown	Cumberland	I. M. Smalley	Grist	16	40	57	

Cohansey Creek and Branches.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	Net.	Gross.	REMARKS.
Cohansey Creek	Bridgeton	Cumberland	R. Lott Estate	Flouring	16	30	45	
" "	"	"	Cumberland Iron Co	Nails and iron pipe	14	100	150	
" "	Cedar Grove	"	Robt. Moore, Frank Barker	Saw and grist	8	35	60	
" "	Deerfield	"	D. Harris	Grist	12	25	36	
Mill Creek	Sheppard's Mill	"	H. J. Young	Flouring	14	20	30	
Barrett's Run	Near Bridgeton	"	Cumberland Iron Co	Saw-mill site				Not in use.
Mill Creek	Fairton	"	Theodore Trenchett	Flouring	17½	50	70	
Branch at Bridgeton	East Bridgeton	"	Jonathan Elmer	"	20	50	80	
" " "	" "	"	East Lake Woolen Co	Saw	20	25	50	
Loper's Run	Bridgeton	"	—— Minch	Grist	18	20	30	
Parsonage Branch	Cedar Grove	"	—— Hand	Grist and saw	8	20	30	

WATER-POWERS OF SOUTHERN NEW JERSEY—Continued.

Cedar Creek and Branches.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED. Net.	H. P. UTILIZED. Gross.	REMARKS.
Cedar Creek	Cedarville	Cumberland	C. O. Newcomb	Flouring	12	50	70	
" "	Lummistown	"	Fred'k Lummis	Saw	10	15	20	
" "	"	"	Clarence B. Lummis	Grist	8	15	20	

Nantuxent Creek.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED. Net.	H. P. UTILIZED. Gross.	REMARKS.
Nantuxent Creek	Newport Station	Cumberland	Peter Henderson, Luke Bateman	Grist	13	20	30	

Dividing Creek and Branches.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED. Net.	H. P. UTILIZED. Gross.	REMARKS.
Dividing Creek	Near Mauricetown Station	Cumberland	Jas. Reeves	Grist	4½	15	22	
Mill Creek	Dividing Creek	"	Peter Ladew	Saw	7	20	30	

Maurice River and Branches.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED. Net.	H. P. UTILIZED. Gross.	REMARKS.
Maurice River	Millville	Cumberland	Millville Manufacturing Co.	Water works	22	40	60	These powers are all on one dam and raceway.
" "	"	"	" " "	Flouring	22	40	60	
" "	"	"	" " "	Blacking mill	22	50	70	
" "	"	"	" " "	Foundry	22	60	85	
" "	"	"	" " "	Bleachery	22	100	145	
" "	"	"	" " "	Cotton factory	22	400	575	
" "	Willow Grove	"	C. P. & T. C. Fox	Flouring	5½	52	75	
" "	" "	Salem	Case Brothers	Saw	5	36	70	
" "	Iona	Gloucester	J. L Buffield	Flouring	6½	13	22	
Manantico Creek	Clark's Mill	Cumberland	(?)	Grist-mill site	6	....	....	Not in use.
Manumuskin Creek	Fries' Mill	"	John Fries	Grist	8	12	20	
" "	" "	"	" "	Saw	8	10	20	

WATER-POWERS OF SOUTHERN NEW JERSEY—Continued.

Maurice River and Branches—Continued.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED.		REMARKS.
						Net.	Gross.	
Manumuskin Creek	Cumberland	Cumberland	R. D. Wood & Co	Saw	9	20	40	
Muskee Creek	Leesburg	"	John Russell	"	....	5	10	
Clear Run	Bricksboro	"	" "	Grist	....	(12)	....	Not in use.
Buckshutem Creek	Buckshutem	"			6	....	....	Old forge site.
Muddy Run	Bradway Station	Salem	Ackley & Garrison	Saw	....	25	40	
" "	Union Grove	"	—— Ackley	"	....	30	60	
" "	Centerton	"	J. R. Fitzhugh	Shoe factory and grist	5½	66	110	
" "	Palatine	"	Estate Geo. Fox	Grist	8	25	45	
" "	"	"	" " "	Saw	8	10	20	
" "	Elmer	"	Robert K. Greenwood	"	5½	12	24	
" "	"	"	W. W. Johnson	Flouring	6½	38	55	
Scotland Run	Malaga	"	A. K. Richmond & Bro	"	6½	25	45	

Streams in Cape May County.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	Net.	Gross.	REMARKS.
West Creek	West Creek	Cape May	Wm. G. Nixon	Saw-mill site	6	(20)	....	Not in use.
East Creek	" "	" "	Charles Hand	Saw and grist	6	20	28	
Dennis Creek	South Dennisville	" "	—— Ludlam	Grist	5	15	22	
Branch west of Dennisville	Dennisville	" "	—— James	Saw	5	15	22	
Branch at Dennisville	"	" "	—— Edwards	Grist	5	15	22	Tide mill.
Sluice Creek	South Dennisville	" "	Jos. L. Hand, L. D. Smith	Saw	6	15	22	
Fishing Creek	Nummytown	" "	Hildreth Estate	Grist	5	15	22	
Cape Island Creek	Cold Spring	" "	" "	Saw	5	15	25	Tide mill.
Mill Creek	South Seaville	" "	Van Gilder Estate	Grist and saw	6	15	22	

WATER-POWERS OF SOUTHERN NEW JERSEY—Continued.

Great Egg Harbor River and Branches.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED.		REMARKS.
						Net.	Gross.	
Great Egg Harbor River	Mays Landing	Atlantic	Mays Landing Water-Power Co.	Cotton goods	10	342	490	
" " " "	Weymouth	"	Charles R. Colwell	Paper mill	13	70	100	Not in use.
" " " "	"	"	" "	Saw	13	30	60	" "
Tuckahoe River	Head of River	Cumberland		Grist and saw	5			Old tide mill; not in use.
" "	Hunter's Mill	"						
Cedar Swamp Creek	Near Mount Pleasant	Cape May	—— Steelman	Grist and saw	6	10	15	
Branch of Tuckahoe	" Marshallville	" "	R. W. Godfrey	" " "	4½	10	15	
" " "	" "	" "	John Wallace	" " "	4½	10	15	
Stephen's Creek	Estellville	Atlantic	—— Steelman	Grist	6	15	22	
" "	"	"	Estell Estate	Saw	6	15	22	
South River	Monroe Forge	"	John Walker	Grist and saw		(50)		Not in use.
" "	Richland	"	—— Smith	Saw	6	10	15	
Deep Run	"	"	—— Pancoast	"	5	12	18	
Hospitality Branch	Cedar Lake	"	Binomen Estate	"	5	15	25	
Patcong Creek	Bargaintown	"	Atlantic City W. W. Co.	Grist	5½	15	22	
" "	"	"	" " "	Saw	6	15	22	
English "	English Creek	"	Baker & Thompson	Grist	9	15	25	
" "	" "	"	" "	Saw	9	10	16	
Gravelly Run	Gravelly Run	"	Judge Abbott	"	5	15	25	
" "	" "	"	—— Tream	"	7	15	25	
Babcock Creek	Mays Landing	"	Charles R. Colwell	Saw-mill site		(50)		Not in use.

Absecon Creek.

Absecon Creek	Near Absecon	Atlantic	A. Doughty	Grist	5	30	45	
" "	Doughty's Mill	"	" "	Saw	5	30	45	

WATER-POWERS OF SOUTHERN NEW JERSEY—Continued.

Doughty's Creek.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED.		REMARKS.
						Net.	Gross.	
Doughty's Creek	Oceanville	Atlantic	....	Mill site	9	....	....	Not in use.

Mullica River and Branches.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED.		REMARKS.
						Net.	Gross.	
Mullica River	Atsion	Atlantic	Jos. Wharton	Grist	9	....	....	Not in use.
" "	"	"	" "	Cotton mill	9	....	....	" "
Nacote Creek	Port Republic	"	Dr. Pitney	Grist	7	20	30	
" "	" "	"	" "	Saw	7	20	30	
Gloucester Lake	Near Gloucester	"	Gloucester Land Co.	"	10	....	....	Not in use.
Hammonton Creek and Atsion River	Pleasant Mills	"	Pleasant Mills Paper Co.	Paper	10	150	200	
Hammonton Creek and Atsion River	Near Hammonton	"	Chas. Weatherbee	Saw	10	20	30	
Batsto River	Batsto	Burlington	Jos. Wharton	Grist	8	12	20	
" "	"	"	" "	Saw	9	20	30	
Muskingum Brook	Indian Mills	"	Jos. Thompson	Grist	14	25	40	
" "	" "	"	A. Woolman	Saw	10	20	33	
Bass River	Bass River	"	The Misses Page	"	8½	30	45	
Wading River	Harrisia	"	Harris & Herrington	Paper	12	225	320	
" "	Speedwell	"	Mrs. Jas. Lee	Old furnace	8	(40)	....	Not in use.
Governor's Hill Branch	Jones' Mill	"	Jones Estate	Saw	9½	12	18	
West Branch	Near Shamong	"	....	Old forge site	....	....	....	Not in use.
Oswego River	Martha	"	Harris & Herrington	Saw	12½	(75)	....	" "
Bull Creek	Herman	"	Johnson Estate	Grist	8	12	18	
" "	"	"	" "	Saw	8	12	18	
Lower Bank Branch	Lower Bank	"	Saml. Weeks Estate	Saw-mill site	8¼	(25)	....	Not in use.
Ives' Branch	Bridgeport	"	Mrs. Ellen Cramer	Grist and saw-mill site	8	(25)	....	" "

WATER-POWERS OF SOUTHERN NEW JERSEY—Continued.

Tuckerton Creek.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED.		REMARKS.
						Net.	Gross.	
Tuckerton Creek	Tuckerton	Burlington	W. W. Pharo	Flouring	7	50	70	
" "	"	"	" "	Saw	7	20	35	

Small Coast Streams of Ocean County.

West Creek	West Creek	Ocean	Chas. Holman	Saw-mill site	6¼	....	....	Not in use.
Cedar Creek	Cedar Run	"	——— Holmes	Saw	6	1	25	
Mill Creek	Manahawken	"	S. T. Oliphant	Flouring	8	40	58	
" "	"	"	" "	Saw	8	18	24	
Waretown Creek	Waretown	"	——— Holmes	Grist	8	25	35	
Oyster Creek	Wells' Mills	"	Jesse Estlow & Bro	Saw	7	20	40	
Forked River	Forked River	"	Holmes Estate	Saw and grist	8½	25	35	
North Branch of Forked River	Near Forked River	"	J. Falkinburgh	Saw	8	25	35	

Cedar Creek and Branches.

Cedar Creek	Double Trouble	Ocean	Capt. Geo. Giberson	Saw	6	40	60	
" "	Dover Forge	"	N. Austen	"	7	30	42	
Middle Branch	Bamber	"	Wm. Harvey	"	9	40	60	
Webb's Mill Branch	Webb's Mill	"	Thos. Hooper Estate	Saw-mill site	....	(15)	....	Not in use.

WATER-POWERS OF SOUTHERN NEW JERSEY—Continued.

Toms River and Branches.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED.		REMARKS.
						Net.	Gross.	
Toms River	Toms River	Ocean	J. Aumack	Grist	6	26	38	
" "	Francis' Mills	"	J. J. Allen	Saw and grist	10	50	80	
" "	Carr's Tavern	"	R. & J. De Bow	Saw	7	22	30	
Jake's Branch	Near Tom's River	"	—— Giberson	Box factory	6	20	40	
Davenport's Branch	" " "	"	D. C. Van Schoick	Saw and turning	8	25	35	
Wrangel Brook	Giberson's Mills	"	Estate of Jas. Giberson	Saw	8	15	22	
Union Branch	Manchester	"	J. S Schultz	Bagging	14	58	80	
Borden's Mill Branch	Collier's Mills	"	E. Emson	Saw	8	15	22	
Branch at Cassville	Cassville	"	A. Van Hise	Saw and planing	8	40	66	

Kettle Creek and Branches.

Polhemus Brook	Silverton	Ocean	J. P. Haines	Saw	7	(15)	....	Not in use.
Main Branch Kettle Creek	Near Cedar Bridge	"	David C. Clayton, Reuben Irons	Grist and saw	7	17	34	

Metedeconk River and Branches.

Metedeconk River	Burrsville	Ocean	Lakewood Land Co.	....	9	....	....	Not in use.
North Branch	"	"	Tunis Lane	Grist	8	18	25	
Polipod Branch	Near Bethel	Monmouth	C. H. Lane	Saw	7	12	17	
North Branch	Georgia	"	Dr. Johnson	"	6	12	24	
South "	Lakewood	Ocean	Lakewood Electric Light and Water Co.	Electric light and water works	9	120	170	
" "	Bennett's Mills	"	Harry Appleget	Grist	9 }	49	70	
" "	" "	"	" "	Saw	9 }	15	22	
" "	Jackson's Mills	"	Matthew Estate	"	7	18	25	
" "	Near Siloam	"	Thos. Thompson	"	6	15	30	

WATER-POWERS OF SOUTHERN NEW JERSEY—Continued.

Manasquan River and Branches.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED.		REMARKS.
						Net.	Gross.	
Manasquan River	Squankum	Monmouth	—— Crickett	Grist and canning	9	35	50	
" "	West Farms	"	Henry V. Layton	Grist	10	32	46	
" "	Turkey	"	J. & P. M. Wyckoff	Flouring	8 }	30	45	
" "	"	"	" "	Saw	8 }	15	22	
Branch at Herbertsville	Herbertsville	"		"	5	15	25	
" south of Turkey	"	"	Levi G. Irvin	"	10½	20	30	
Mingumhone Brook	Farmingdale	"	I. Van Note	"	9	18	25	
Branch east of Fairfield	Fairfield	"	Wm. Maps	"	10	20	30	
" at Turkey	Turkey	"	Chas. Hall	Grist	9	20	30	

Wreck Pond and Branches.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	Net.	Gross.	REMARKS.
Wreck Pond	Near Bailey's Corners	Monmouth	Mrs. Chas. Osborn	Grist	6	10	14	
Great Branch	Bailey's Corners	"	Abr. Osborn	Saw	6	10	14	
" "	Near New Bedford	"	J. W. Border	"	8	10	20	

Shark River and Branches.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	Net.	Gross.	REMARKS.
Shark River	Shark River	Monmouth	Remsen Estate	Flouring	10	....	....	Not in use.
" "	Near Shark River Station	"	Monroe Shafto	Saw	8	15	22	
" " Branch	" " " Village	"	Bowman Kisner	Grist	10	15	25	

Whale Pond and Branches.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	Net.	Gross.	REMARKS.
Whale Pond Branch	Deal	Monmouth	Long Branch Water Co.	Flouring	9⅓	18	26	
Cranberry Brook	Poplar	"	Edward Wheeler	Old mill-site (saw)	10	....	....	Not in use.

WATER-POWERS OF SOUTHERN NEW JERSEY—Continued.

Shrewsbury River and Branches.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED.		REMARKS.
						Net.	Gross.	
Pleasure Bay	West Long Branch	Monmouth	G. F Baker	Grist	7	....	....	Not in use.
Parker's Creek	Eatontown	"	J. Johnson	"	12	20	30	

Navesink River and Branches.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	Net.	Gross.	REMARKS.
Swimming River	Scobeyville	Monmouth	Van Mater & Muhlenbrink	Grist	10	25	40	
Yellow Brook	Colts Neck	"	Frank Heyer	Saw	13	46	66	
" "	" "	"	Wm. C. Buck	Grist	9½	33	47	
Hockhockson Brook	Tinton Falls	"	S. J. Bennett	Flouring	28	35	50	
" "	" "	"	" "	Saw	28	15	22	
Pine Brook	" "	"	D. H. Cook	"	8	(15)	....	Not in use.
Colts Neck Branch	Colts Neck	"	Schneider & Gaskell	Grist	21	28	40	
Hop Brook	Edinburgh	"	Estate of Chas. Taylor	"	9	(30)	....	Not in use.
" "	Marlboro	"	Peter D. Stillwell	"	16	25	36	
Willow Brook	Holmdel	"	Thos. Ely	"	15	45	65	

Waycake Creek and Branches.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	Net.	Gross.	REMARKS.
Waycake Creek	Near Keansburg	Monmouth	A. L. Phillips	Saw and flouring	11	30	45	
Mahoras Brook	Middletown	"	Chas. Allan	Flouring	8	25	36	

Flat Creek.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	Net.	Gross.	REMARKS.
Flat Creek	Near Mechanicsville	Monmouth	Anna Walling	Grist	6½	(20)	....	Not in use.

APPENDIX II.

THE DRAINAGE SYSTEMS OF NEW JERSEY.

AREAS, PERCENTAGE OF FOREST, POPULATION. THE AREAS AND DRAINAGE AREAS OF LAKES AND PONDS.

DRAINAGE AREAS, FORESTED AREAS AND POPULATION (1880) OF STREAM BASINS.

	Square miles.	Percentage of forest.	Population per square mile.
WALLKILL, TO STATE LINE	210.1	20	41
Pochuck creek, to State line	53.7	55	25
Wawayanda lake	6.5	64	35
Papakating creek	62.2	14	58
Wallkill to Franklin Furnace	31.3	51	26
Morris pond	1.5	66	....
HACKENSACK RIVER, TOTAL WATER-SHED	201.6	*36	216
Hackensack above New Milford	114.8	*60	125
Hackensack above Pascack creek	58.0	....	....
Hackensack in New York	64.1	....	152
Pascack creek	28.0	....	....
Musquapsink creek	7.0	....	....
PASSAIC RIVER, TOTAL WATER-SHED	949.1	*44	338
Passaic river above Dundee dam	822.4	....	....
Passaic river above falls at Paterson	796.9	....	85
Passaic river above Little Falls	772.9	....	....
Passaic river in New York	148.6	....	42
Second river	17.2	10	1,400
Third river	14.4	23	276
SADDLE RIVER, TOTAL WATER-SHED	60.7	*28	122
Saddle river in New York	8.0	....	84
Hohokus creek above Hohokus	15.7	34	59

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* Percentage of portion lying within New Jersey.

	Square miles.	Percentage of forest.	Population per square mile,
POMPTON RIVER, TOTAL WATER-SHED	379.9	*69	48
RAMAPO RIVER, TOTAL WATER-SHED	160.7	*72	58
Ramapo in New York	112.4		52
WANAQUE RIVER, TOTAL WATER-SHED	109.6	*83	30
Wanaque in New York	28.2		22
Greenwood lake, total water-shed	28.0	*81	26
Greenwood lake in New York	10.2		22
PEQUANNOCK RIVER	84.8	78	42
Pequannock above Macopin intake	63.7		
Macopin lake	2 5	50	30
Pequannock to Oak Ridge reservoir	27.6		
Stickle pond	1.7	100	
Mossman's brook to Clinton reservoir	9.9		
Hank's pond	.7	100	
Cedar pond	1.0	100	
Buck-a-bear pond	1.2	100	
Dunker pond	2.7	70	15
ROCKAWAY RIVER, TOTAL WATER-SHED	138.4	80	110
Rockaway above Boonton	118.2	82	113
Stony brook.	12.7		
Shongum pond	2.9	65	138
Beaver brook	22.1		
Splitrock pond	5.3	98	5
Green Pond brook	16.4	87	51
Green Pond brook to Middle Forge	10.1		
Green pond to outlet	1.7	82	
Rockaway above Port Oram	29.9	90	42
WHIPPANY RIVER	71.1	36	124
Troy brook	15.2	34	87
Whippany above Morristown	25.4	55	107

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* Percentage of portion lying within New Jersey.

	Square miles.	Percentage of forest.	Population per square mile.
PASSAIC ABOVE CHATHAM	99.8	23	121
Passaic above Millington	53.6	26	140
Passaic above Franklin	9.2	....	....
ELIZABETH RIVER TO LAKE URSINO	17.4	13	228
RAHWAY RIVER	83.3	24	338
Robinson's branch	22.8	22	183
Rahway river above Rahway city	41.0	30	350
West branch of Rahway above Orange reservoir	5.0	44	70
RARITAN RIVER	1,105.3	16	105
SOUTH RIVER	132.8	25	83
Manalapan brook to junction with Matchaponix	42.2	19	84
Matchaponix brook	45.2	14	86
LAWRENCE'S BROOK ABOVE WESTON'S MILLS	45.0	17	59
RARITAN ABOVE NEW BRUNSWICK	895.2	13	93
Bound Brook, including Green brook	61.5	22	330
Middle brook above Chimney rock	16.7	24	43
MILLSTONE RIVER	285.7	9	78
Beden's brook	49.9	11	59
Stony brook	64.8	8	79
Millstone above forks of Stony brook	98.8	12	75
NORTH BRANCH OF RARITAN	191.6	13	72
Lamington or Black river	91.8	14	80
Lamington above Pottersville	33.0	....	....
Rockaway creek	39.4	12	66
North Branch above forks of Lamington	63.6	16	79
North Branch above Peapack brook	29.1	....	....
SOUTH BRANCH OF RARITAN	276.5	13	79
South Branch to Califon	56 0	....	....
South Branch and Turkey brook	11.3	....	....
Neshanic river	56.3	6	81

	Square miles.	Percentage of forest.	Population per square mile.
Spruce run, including Mulhockaway creek	41.2	15	83
Budd's lake	4.5	24	62
NAVESINK RIVER	95.0	....	....
Swimming river above Red Bank	65.4	11	58
Hockhockson brook above Tinton Falls	11.7	52	51
SHREWSBURY RIVER TO SEABRIGHT BRIDGE	29.0	....	....
WHALE POND BROOK	5.1	35	151
DEAL LAKE	6.1	....	....
SHARK RIVER, TO BRIDGE AT HEAD OF BAY	16.9	59	162
WRECK POND	12.8	29	118
MANASQUAN RIVER	80.5	....	....
Manasquan above Upper Squan bridge	64 7	32	82
METEDECONK ABOVE BURRSVILLE	73.9	68	25
North Branch of Metedeconk	43.2	....	....
South Branch of Metedeconk	29.5	....	....
South Branch of Metedeconk above Lakewood	24.5	75	18
TOMS RIVER ABOVE VILLAGE BRIDGE	163.8	94	17
Toms river above Ridgway branch	58.0	....	....
Toms river above White's bridge	45.0	....	....
Ridgway branch	64.9	....	....
Union branch	30.0	....	....
Horicon branch to Manchester pond	21.0	....	....
Davenport branch to Van Schoick's mill	34.0	....	....
CEDAR CREEK ABOVE VILLAGE	55.8	99	7
Cedar creek to Double Trouble	44.8	....	....
FORKED RIVER ABOVE VILLAGE	14.7	98	7
MILL CREEK ABOVE MANAHAWKEN	19.7	97	6
WESTECUNK CREEK ABOVE WEST CREEK BRIDGE	21.0	96	5
TUCKERTON CREEK ABOVE TUCKERTON	11.9	93	25
MULLICA RIVER	569.6	90	22

	Square miles.	Percentage of forest.	Population per square mile.
Bass river above New Gretna road	16.8	95	11
Wading river	188.9	97	7
East branch of Wading river	65.5	98	6
West branch of Wading river	92.1	99	7
Mullica river above forks of and including Batsto river	221.6	88	19
Atsion and Mechescatauxin to Batsto	73.2	....	....
Batsto river to Batsto	69.1	....	....
Nescochague to Pleasant Mills	35.0	....	....
Hammonton brook to Pleasant Mills	18.3	....	....
ABSECON CREEK ABOVE ABSECON	18.3	97	8
PATCONG CREEK ABOVE STEELMANSVILLE	22.1	81	53
GREAT EGG HARBOR RIVER	337.7	88	21
Great Egg Harbor river above Mays Landing	215.8	88	26
Great Egg Harbor river above Weymouth	192.0	....	....
Great Egg Harbor river above New Jersey Southern railroad	51.0	....	....
Hospitality branch	50.5	....	....
Babcock's creek, Mays Landing	21.2	98	12
Deep run to forks	22.6	....	....
South river, Monroe forge	19.0	....	....
Stephen's creek to Estellville	10.5	....	....
TUCKAHOE RIVER	99.8	81	15
Tuckahoe river above Tuckahoe	60.2	95	9
MAURICE RIVER	386.4	70	72
Buckshutem creek	18.8	....	....
Manumuskin creek	38.7	94	17
Manantico creek	38.7	79	38
Maurice river above Millville	218.4	67	63
Maurice river above Landis avenue	114.1	66	55
Maurice river, West branch to Rosenhayn	53.1	....	....

	Square miles.	Percentage of forest.	Population per square mile.
COHANSEY CREEK	105.4	20	140
Cohansey creek above Bridgeton	45.8	13	54
DELAWARE RIVER IN NEW JERSEY	2,344.8	30	129
ALLOWAYS CREEK ABOVE HANCOCK'S BRIDGE	51.6	27	58
Alloways creek above Alloway	21.9	....	....
SALEM CREEK	113.6	10	123
Salem creek above Sharptown	22.6	8	112
OLDMAN'S CREEK	44.4	14	52
Oldman's creek above Auburn	26.3	18	46
RACCOON CREEK	44.4	12	91
Raccoon creek above Swedesboro	32.2	12	68
Raccoon creek above Mullica Hill	13.1	....	....
MANTUA CREEK	51.2	16	106
Mantua creek above Berkeley	46.7	17	83
BIG TIMBER CREEK	59.3	25	83
North branch of Big Timber creek	19.8	27	68
South branch of Big Timber creek	25.5	27	62
COOPER'S CREEK	40.5	16	208
Cooper's creek, south branch	18.1	21	62
Cooper's creek, north branch	11.7	16	65
PENSAUKEN CREEK	35.4	10	109
South branch of Pensauken	14.9	12	118
North branch of Pensauken	17.1	7	71
RANCOCAS CREEK	341.4	61	58
South branch of Rancocas	167.1	57	40
Haynes creek	77.1	....	....
South branch above Vincentown	53.3	....	....
North branch of Rancocas	143.7	75	62
North branch to New Lisbon	31.2	....	....
Mt. Misery brook to New Lisbon	75.1	....	....

	Square miles.	Percentage of forest.	Population per square mile.
ASSISCUNK CREEK	45.3	4	58
BLACK'S CREEK TO MANSFIELD SQUARE POND	20.7	....	....
CROSSWICKS CREEK	139.2	20	52
Crosswicks creek to Walnford	79.9	....	....
Doctor's creek to Yardville	26.7	....	....
Doctor's creek to Allentown	17.3	....	....
Back creek to Lowry's pond	8.0	....	....
ASSANPINK CREEK	89.6	9	253
Assanpink to Lawrence station	34.7	....	....
Miry run	13.0	....	....
JACOB'S CREEK	13.3	9	72
ALEXSOCKEN CREEK	14 9	18	60
WICKECHEOKE CREEK	26.9	13	67
LOCKATONG CREEK	23.8	15	45
NICHISAKAWICK CREEK	10.5	13	45
HARIHOKAKE CREEK	10.1	13	46
HAKIHOKAKE CREEK	17.4	16	48
MUSCONETCONG RIVER	157.6	39	71
Musconetcong above Hackettstown	74.6	....	....
Musconetcong above Saxton Falls	68.0	....	....
Musconetcong above New Hampton	122.4	....	....
Musconetcong above Warren Mills	149.9	....	....
Lubber's run	24.1	87	15
Lake Hopatcong	25.4	94	30
POHATCONG CREEK	56.2	19	129
LOPATCONG CREEK	13.5	....	....
PEQUEST RIVER	158.2	18	58
Pequest at Townsbury	83.4	....	....
Pequest at Tranquility	34.8	....	....
Beaver brook	37.1	18	47

	Square miles.	Percentage of forest.	Population per square mile.
Beaver brook at Hope	9.4	....	....
PAULINSKILL	177.4	27	54
Paulinskill at Balesville	66.3	....	....
Swartswood lake	16.3	22	33
Culver's pond	6.3	83	30
Long pond	2.5	80	30
FLAT BROOK	65.7	54	21
Big Flat brook to Forks	33.0	....	....
Little Flat brook to Forks	16.5	....	....
*Delaware at Port Jervis	3,252	....	....
Delaware below mouth of Neversink	3,600	....	....
Delaware at Water Gap, above Broadhead's creek	4,020	....	....
Delaware at Belvidere, below Pequest	4,708	....	....
Delaware at Easton, above Lehigh river	4,880	....	....
Delaware at Easton, below Lehigh river	6,212	....	....
Delaware at Bull's Falls	6,750	....	....
Delaware at Lambertville	6,820	....	....
Delaware at Scudder's Falls	6,894	....	....
Delaware at Trenton	6,916	....	....
Delaware at Philadelphia	8,186	....	....
Delaware below mouth of Schuylkill	10,100	....	....

* These areas of the Delaware water-shed are taken from Prof. Geo. F. Swain's report in Volume 16, Tenth Census, and appear to be as nearly correct as existing surveys will admit of.

SURFACE AREA AND TRIBUTARY DRAINAGE AREA OF LAKES AND PONDS.

	Area of Water Surface—Acres.	Drainage Area—Square Miles.
ATLANTIC COUNTY.		
Bargaintown, lower pond	73	20.66
Bargaintown, upper pond	57	11.77
Gloucester lake	85	23.58
Mays Landing mill-pond	333	215.8
Pleasant Mills, south pond	51	....
Weymouth mill-pond	205	192
BERGEN COUNTY.		
Franklin lake	89	2.41
Rotten pond	25	1.06
BURLINGTON COUNTY.		
Atsion mill-pond	77	43.71*
Batsto, east pond	89	69.7
Brown's Mills pond	45	27.03
Hanover Furnace pond	103	13.12
Harrisville mill-pond	101	155
CUMBERLAND COUNTY.		
Bridgeton mill-pond	85	45.8
Millville mill-pond	926	218.4
Willow Grove mill-pond	118	....
ESSEX COUNTY.		
Orange reservoir	64	4.80
GLOUCESTER COUNTY.		
Clayton mill-pond	69	7.84
Malaga Furnace pond	92	27.86
MIDDLESEX COUNTY.		
Weston's Mills pond	64	45

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*Includes 18.02 from Mechescatauxin by a canal.

MONMOUTH COUNTY.	Area of Water. Surface—Acres.	Drainage Area—Square Miles.
Como lake	50	1.26
Deal lake	144	6.16
Silver lake	14	.26
Spring lake	18	.30
Sunset lake	18	......
Takanassee lake (Whale pond)	29	5.1
Wesley lake	18	......
MORRIS COUNTY.		
Budd's lake	475	4.5
Denmark pond	172	4.5
Dixon's pond	35	3.5
Durham pond	47	......
Green pond	460	1.7
Hopatcong lake	2,443	25.4
Middle Forge pond	96	10.1
Mooseback pond	21	....
Petersburg mill-pond	53	....
Shongum pond	70	2 9
Splitrock pond	315	5.3
Stickle pond	110	1.7
OCEAN COUNTY.		
Carasaljo lake (Lakewood)	97	24.80
Cook's pond	22	....
Little Silver lake	16	.24
Manahawken mill-pond	98	19.7
Old Sam's pond	28	....
Twilight lake	21	....
PASSAIC COUNTY.		
Buckabear pond	59	1.2
Cedar pond, recently enlarged	218	1
Charlottesburgh mill-pond	42	....
Clinton reservoir—Newark water works	423	9.5
Dunker pond	17	2.7
Dundee lake	224	8.22
Greenwood lake (total area)	1,920	28
Hank's pond	75	.7
Macopin lake	299	2.5
Mud pond	28	....
Negro pond	69	1.04
Oak Ridge reservoir, Newark water works	383	27.3
Pompton lake	196	159.5
Sheppard's pond	97	.76
Tice's pond	20	.65

SALEM COUNTY.	Area of Water Surface—Acres.	Drainage Area—Square Miles.
Alloway mill-pond	122	21.9
SUSSEX COUNTY.		
Bear ponds	38	.58
Buckmire pond	10	.75
Catfish pond (near Stillwater)	14	.40
Cranberry reservoir	154	3.02
Culver's pond	486	6.3
Davis pond	14	.51
Decker pond (Pochuck mountain)	76	.38
Franklin Furnace pond	55	31.3
Hewitt's pond	35	5.15
Hopewell Furnace pond	24	1.01
Howell's pond	26	.21
Hunt's pond	37	2.12
Iliff's pond	36	3.38
Lane's pond, or Grinnell lake	67	1.15
Little pond (Swartswood)	100	3.11
Long pond (near Culver's Gap)	299	2.5
Long pond (near Andover)	117	4 76
Long pond (Kittatinny mountain)	13	.46
Losee pond	137	....
Marcia lake	23	.14
Mashipacong pond	46	.77
Morris pond	136	1.5
Mud pond (Hamburg mountain)	28	.36
Panther pond	41	.47
Quick pond	43	.50
Roe pond	23	....
Round pond (Kittatinny mountain)	33	.29
Sand pond (near Coleville)	65	.65
Sand pond (Hamburg mountain)	32	.48
Stag pond	23	.30
Stanhope reservoir	339	4.9
Stickle pond	35	.87
Sucker pond	95	1.15
Swartswood lake	505	16 3
Turtle pond	13	.10
Waterloo pond	68	....
Wawayanda lake	240	6.5
White lake	17	....
White's pond	11	....
Wright's pond	31	3.36

WARREN COUNTY.	Area of Water Surface—Acres.	Drainage Area—Square Miles.
Allamuchy pond	56	1.80
Catfish pond	31	.65
Cedar lake (near Blairstown)	27	1.25
Glover's pond	13	.28
Green's pond	117	5.15
Sand pond	14	.69
Shuster pond	14	.64
Silver lake	35	3.37
Sunfish pond	41	.31
White pond	67	.67

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